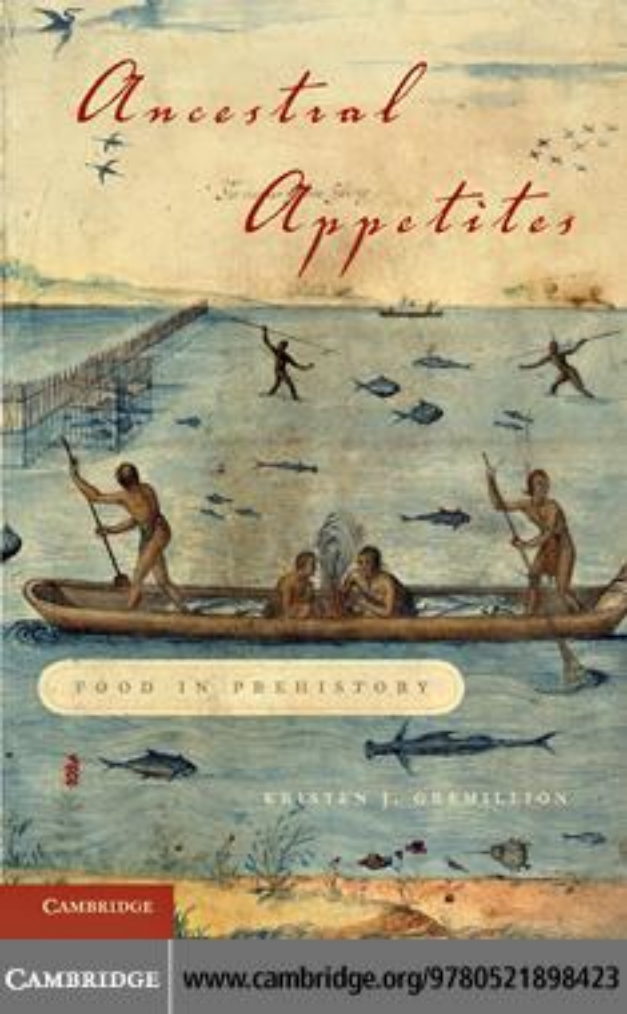


A detailed illustration of a prehistoric fishing scene. In the foreground, a long wooden canoe carries four people: two standing at the bow and stern using long poles to spear fish, and two seated in the middle. The water is filled with numerous fish of various sizes. In the background, two more individuals are wading and spearing fish. To the left, a long wooden pier or net structure extends into the water. The sky is filled with several birds in flight. The overall style is that of a classical painting.

Ancestral Appetites

FOOD IN PREHISTORY

KRISTEN J. GEMILLION

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ANCESTRAL APPETITES

This book explores the relationship between prehistoric people and their food – what they ate, why they ate it, and how researchers have pieced together the story of past foodways from material traces. Contemporary human food traditions encompass a seemingly infinite variety, but all are essentially strategies for meeting basic nutritional needs developed over millions of years. Humans are designed by evolution to adjust our feeding behavior and food technology to meet the demands of a wide range of environments through a combination of social and experiential learning. In this book, Kristen J. Gremillion demonstrates how these evolutionary processes have shaped the diversification of human diet over several million years of prehistory. She draws on evidence extracted from the material remains that provide the only direct evidence of how people procured, prepared, presented, and consumed food in prehistoric times.

Kristen J. Gremillion is an Associate Professor in the Department of Anthropology at The Ohio State University. She has published many articles on human dietary variability in journals including *American Antiquity*, *Current Anthropology*, and *Journal of Archaeological Science* as well as chapters in several edited volumes.

ANCESTRAL APPETITES

Food in Prehistory

KRISTEN J. GREMILLION

The Ohio State University



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Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Tokyo, Mexico City

Cambridge University Press

32 Avenue of the Americas, New York, NY 10013-2473, USA

www.cambridge.org

Information on this title: www.cambridge.org/9780521727075

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First published 2011

Printed in the United States of America

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication data

Gremillion, Kristen J., 1958–

Ancestral appetites : food in prehistory / Kristen J. Gremillion.

p. cm

Includes bibliographical references and index

ISBN 978-0-521-89842-3 (hardback) – ISBN 978-0-521-72707-5 (paperback)

1. Prehistoric peoples – Food. 2. Hunting and gathering societies.

3. Food habits – History. 4. Food preferences – History. 1. Title.

GN799.F6G74 2011

394.1'209012 – dc22 2010044632

ISBN 978-0-521-89842-3 Hardback

ISBN 978-0-521-72707-5 Paperback

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To Paul

*Let me not to the marriage of true minds
admit impediments.*

Shakespeare, Sonnet 116

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PREFACE AND ACKNOWLEDGMENTS

HUMAN DIETS AND THEIR CULTURAL AND EVOLUTIONARY ROOTS HAVE been at the center of my research efforts over the last two decades. In my own laboratory, I investigate paleodiet through the identification and analysis of ancient plant remains (an “arcane subspecialty,” as one acquaintance described it). Perhaps it was the recognition that the more technical aspects of the work were of interest to only a small subset of my colleagues that initially kept me from seeing that research into ancient human diets has the potential to reach a wider audience. However, there was another factor – the enormous increase in the quantity and quality of relevant data over the past few decades. New techniques for extracting information from a wide variety of archaeological materials are featured with great regularity in journals such as the *Journal of Archaeological Science*. Both methods and theoretical frameworks for better understanding human diets have proliferated in recent years, making it difficult indeed to keep up with developments.

It was during the process of trying to help students understand and work with this vast array of new information that the idea for this book began to germinate. In developing a graduate seminar on paleodiet, I decided to emphasize the variety of methods now available and what they might be able to teach us. In particular, I wanted to provide some guidance on how the various techniques, currently springing up like mushrooms after rain, could inform students’ own research. We also explored key controversies such as the role of human hunters in species extinctions, the importance of domesticates in the diets of incipient farmers, the role played by meat consumption in human evolution, and the documentation of cannibalism in the prehistoric record.

It occurred to me that most of the public was largely ignorant of these developments because so much of the information remained buried in

specialized journals. This book was designed to correct this state of affairs by giving readers a taste of the evidence, oriented around some major transitions in human diet and food technology. So although it covers several million years of human history, it is not intended to be comprehensive; rather, I hope the book serves as a kind of “consciousness-raising” exercise (yes, I was a college student in the 1970s) that might correct the misconception that we know very little about how and what prehistoric people ate. In addition, I wanted to show how evolutionary thinking might be applied to the important business of acquiring and consuming food. We enjoy greater dietary flexibility than most species; however, this ability to improvise itself evolved in the distant past, for reasons that are still imperfectly understood. Humans also “inherit” food customs, building bodies of knowledge that accumulate over many generations and depend on the subtleties of language to invest them with meaning. Human food choices have roots in biological needs, individual preferences, and evolutionary history, but their great diversity across the globe would not exist without the system of social learning known as culture.

Many people have helped me in various ways to bring this project to fruition. I thank my colleagues who read and commented on the book prospectus and the resulting manuscript (Paul Gardner, Clark Larsen, Ken Sassaman, Greg Waselkov, and one anonymous reviewer) for generously investing their time and offering many helpful comments. This book owes its origin to my role as a teacher, and the graduate students enrolled in my paleodiet seminar in the Department of Anthropology at The Ohio State University have enriched my understanding by asking many good questions and sharing their own specialized knowledge. Over the years, many colleagues have helped me refine my ideas, both through formal critique and informal (and often beer-fueled) discussions. Although I could not possibly name them all, they include William S. (Bill) Dancey, Julie Field, Gayle Fritz, Paul Gardner, Julia Hammett, Cecil Ison, Andrew Mickelson, Katherine (Kappy) Mickelson, Dolores Piperno, Bruce Smith, Bruce Winterhalder, Jean Black Yarnell, Richard A. (Dick) Yarnell, and Melinda (Mindy) Zeder. The rest of you, I hope, know who you are, and will also accept my grateful thanks.

This book would have taken many years to complete without the support of The Ohio State University in the form of a faculty professional leave, which allowed me to devote my time to writing. Ohio State, the USDA Forest Service, the National Science Foundation, the Kentucky Heritage Council, and the National Geographic Society have

all provided key financial support for my research projects over the years. Without it, I would not be the scholar I am today.

Beatrice Rehl of Cambridge University Press encouraged me to develop a proposal for this book and gave me valuable advice on how to make it better. Without her input and encouragement, I suspect that the road to publication would have been much longer and rougher than it turned out to be.

INTRODUCTION

EVERY MEAL WE EAT TELLS AN EVOLUTIONARY TALE WHOSE BEGINNINGS go back to the origin of life itself. That hot dog you ate for lunch has a surprisingly rich history, one that reflects the cumulative wisdom of natural selection, a multitude of human decisions, and the structured flow of information that we call human culture. Pursuing the origins of your lunch is not easy, for the farther back you go in time, the more sparse and ephemeral the evidence. Cattle were domesticated at least 9,000 years ago, and the wheat in the bun even earlier. The original wild forms of wheat were coaxed by incipient farmers into producing greater yields over generations of planting, harvesting, and planting again. The grinding stones used to make flour represent the accumulated knowledge of generations of skilled workers who learned from their elders what stones to select and what forms to create, adding their own improvements to pass on to their children. Is it a kosher hot dog? Behind its manufacture lies a deep cultural tradition of ethnic pride and religious observance. Keep going backward in time, and you find your distant ancestors acquiring a taste for meat and perhaps devising ways to unearth tubers and crush seeds and nuts. Eventually you will arrive at the evolutionary novelty of eating itself – extracting energy not directly from the sun, but from organic matter. All of this history, and more, is embodied in even the most hurried and unreflective act of eating.

All humans share a suite of dietary traits that have been retained over millennia of natural selection because of their survival value. Some of these traits are built into the animal lineages to which we belong – the digestive tract we possess as multicellular animals, for example, and the manual dexterity and keen vision characteristic of primates. However, these ancestral features cannot explain the great diversity of human

foodways. For that we must turn to two key human adaptations that together form a resilient, but flexible, system for generating and selecting among a multitude of feeding patterns. This system combines an open behavioral program that allows us to respond rapidly to changing environmental conditions with a uniquely complex form of cumulative social learning – culture.

Like most mammals, and especially as primates, we have a versatile behavioral repertoire; when it comes to inventing ways to catch, harvest, prepare, and consume food, we have no rivals. However, this level of creativity comes at a price: It costs us both time (for learning) and energy (the extra fuel needed to run a complex brain). For most animal species, these costs place an upper limit on behavioral flexibility, but humans have evolved a mechanism that breaks through this limitation: accumulation of cultural knowledge between generations. Children learn what counts as food, how to prepare a meal, and how to sharpen an arrow point or plant yams from their parents and other adults rather than having to figure things out by themselves each generation. In this way, culture allows us to perpetuate dietary solutions that work well in a given environment without having to follow a behavioral script closely specified by the genes. At the same time, systems of social knowledge remain open to innovations that might make for greater security and efficiency in the quest for food. We enjoy the best of both worlds: the wisdom of tradition coupled with the ingenuity of invention.

The genetically transmitted information we get from our parents and their parents, all the way back to the first life forms, sets the biological foundations for individual decisions about what to eat and how to go about getting it. The part of this heritage that varies from one individual to the next may explain why one likes anchovies or chocolate or beets and others do not. However, genes seldom explain dietary differences between groups of people; these correspond much more closely to the demands of local environments (which inspire technological innovation) and the accumulation of cultural knowledge than they do to biological inheritance. Evolutionary history does offer insights into some of the features of human diet that are widely shared or universal within our species. Many of these are also characteristics of broader groupings of animals, such as primates, mammals, vertebrates, and animals in general.

Consider broccoli, for example. You may not care for it, but your body's ability to convert it to energy at all is owing to shared ancestry

with other animals. Being a primate means it is likely that something green will seem edible to you. However, the fact that this curious cluster of immature flower buds qualifies as proper food you owe to social learning. Knowledge about broccoli, how to cook it (or not), what to serve it with, or whether to serve it at all – these bits of information are acquired from others, whether parents, peers, or celebrities. The culinary merits of broccoli were not simply handed down from nature, fully formed and ready to be implemented. People had to learn first about broccoli's wild relatives, members of the species *Brassica oleracea*. Trial and error revealed the best ways to cultivate this species and how to select for different varieties. Experimentation with methods of cooking produced broccoli steamed, boiled, raw, pureed to make soup, and dipped in tempura batter. These culinary customs, therefore, ultimately derive from the human facility for behavioral innovation, although they would never have accumulated without culture to pass on what individuals have learned over many generations. In this way, innovation is balanced and complemented by imitation – an efficient system that combines individual learning and experimentation with the less costly option of copying what others do.¹

In this book, I explore how this complex system of dietary adaptation developed to generate the diversity of human foodways present today. The first few chapters cover several million years and emphasize the evolution of the dietary adaptations of the human species that shape foodways everywhere. The time scale is long, compared to later periods, and the geographic area restricted initially to Africa, the birthplace of the human lineage. The best-documented changes in diet have been inferred from human anatomy, bone chemistry, and traces of early material culture and are usually understood in terms of the evolutionary processes that affect all biological lineages. These processes remain important but have less explanatory power as human foodways begin to diversify along with the geographic expansion of the genus *Homo* out of Africa more than 1.5 million years ago. By 100,000 years ago – perhaps sooner – the two key human adaptations of behavioral innovation and culture begin to drive dietary diversity at a pace that could not have been matched by selection acting on genetic variation exclusively. Approaching the present, the archaeological record of human diet and subsistence grows in quantity and quality as food technology becomes more diverse and complex and as the likelihood of preservation of perishable remains increases. The diversity of behavior reflected

in archaeological assemblages requires a close look at how behavioral innovation and social learning operate to fine-tune dietary strategies to adjust to the local roster of flora and fauna, seasonal rhythms of food availability, and the social environment.

Both individual decisions about what and how to eat and the shifting frequency of different food habits at the group level are subject to the historical influences that affect every species – natural disasters, changes in global climate or local environmental conditions, and the fortunes of other organisms with which we coexist. For this reason, I approach the prehistory of food in a roughly chronological fashion, to show the developmental trajectory of shared human food habits and the divergence of foodways as people colonized new habitats and developed technologies to exploit them. I track major developments, including the refinement of hunting and gathering, the origins of agriculture, and the effects of social inequality on how people consume food. Finally, I discuss the relevance of food prehistory to contemporary concerns such as extinctions, environmental degradation, conservation, and nutrition.

Much of human activity is tied, either directly or indirectly, to the quest for food. Our need for nutrition constantly reaffirms our kinship with and dependence on other life forms, truths to which millions of years of evolution bear witness. But we also diverge from the rest of nature in the unique system that juggles biological inheritance, behavioral innovation, and culture to keep us fed. That same system has allowed humans to populate the Earth and dominate its ecosystems to an extent that no other species has replicated. How this came about is something only humans have the power, and the responsibility, to understand and remember.

1

ANCESTORS

The world, it has often been remarked, appears as if it had long been preparing for the advent of man: and this in one sense is strictly true, for he owes his birth to a long line of progenitors.

Darwin, *The Descent of Man*

The maintenance of life, through the constant acquisition of food, is the great burden imposed on existence in all species of animals.

Lewis H. Morgan, *Ancient Society*

All animals must eat. In this respect, at least, we are no different from other heterotrophs – we take in solar energy indirectly, by consuming other organisms. This way of life has characterized multicellular animals since their origins more than five million years ago. But heterotrophy is a broadly defined ecological category that gives no hint of the diversity of feeding methods and adaptations found among animals. That these adaptations – morphological, developmental, or behavioral – vary in regular ways between species, genera, families, and even higher taxonomic groups is today a noncontroversial assumption among evolutionary biologists. Still fiercely debated, however, is the hereditary basis of feeding strategies: Which behaviors and preferences are more or less fixed by genetic inheritance and which are free to vary in response to the individual's environment?

This question becomes enormously complicated when we turn to our own species, *Homo sapiens*. Humans have a degree of behavioral flexibility that is orders of magnitude beyond that of other species. To understand that this is true, consider the great variety of ways in which humans choose, acquire, prepare, share, and think about food. This level of diversity makes any other animal species look remarkably homogeneous by comparison. Even dogs, which behave like omnivores

around humans despite their carnivore ancestry, are unlikely to share food willingly, much less set the table, fashion a tortilla, or prepare beef jerky. When it comes to food and eating, humans win the dietary diversity contest hands down.

Whereas some types of cultural information reach far back into the human lineage, it is genetic inheritance that connects us with the earliest life on the planet. Traces of this ancestry remain in the genetically based characteristics that we share with our most distant present-day relatives. Shared traits form the basis for biological taxonomy, the classification of living things. Biologists recognize a hierarchy of nested categories, the most familiar of which are those that make sense to the lay observer as well as the scientist – for example, class (mammals, *Mammalia*), order (rodents, *Rodentia*), genus (Old World mice, *Mus*) and species (the house mouse, *Mus musculus*). Each such category, or taxon, is defined by particular traits shared by all its members. A taxon is a *clade* if it includes all the descendants of a common ancestor and *only* those descendants. Members of a clade share unique features that can be traced back to the founding ancestor in which they originated. For example, members of the mammal clade – Class *Mammalia* – lactate in order to feed their young, an evolutionary innovation that sets them apart from other vertebrate groups. By reviewing such diagnostic traits as we proceed up the taxonomic hierarchy (from more inclusive groups to less inclusive), we should be able to get a good sense of how the feeding habits of humans reflect deep ancestral patterns. Millions of generations of genetic instructions have set the parameters within which we must operate to nourish ourselves.¹ This evolutionary history, from early multicellular animals up to the bipedal apelike australopithecines and finally to modern people, continues to shape human diets today.

OUR ANCIENT HERITAGE

As Vertebrates

Whereas most animals pursue food actively, they do so with varying strategies and degrees of voluntary control over their movements. In fact, the very term “voluntary” implies some sort of consciousness, or at the very least a nerve center carrying out executive functions. Although philosophers and neuroscientists might wish to debate about whether mollusks and insects have desires and intentions, such a claim is less controversial when we come to vertebrates. Vertebrates have

internal skeletons oriented around a linear bony structure, at one end of which lies a head encased within a protective shell (the cranium). The vertebrate skeleton yields an interesting array of anatomical options to facilitate feeding, such as specialized structures for grasping and locomotion. Such adaptations are not unique among vertebrates, as anyone who has ever watched a praying mantis at mealtime will immediately recognize. However, the vertebrate brain and sensory apparatus guide these structures along pathways that are both precise and malleable, lending a degree of behavioral flexibility that seems to be very alien to the insect brain. The difference seems subtle when we compare the darting tongue of a frog to a spider scurrying to capture its entangled prey. But consider mammals: a dam-building beaver, a grazing gazelle alert for predators, a wood rat's cache of seeds, or a bear fishing for salmon. Clearly there is something about mammals that brings the agility of the vertebrate mental apparatus into sharp focus. It is to our mammalian nature that we turn next.

As Mammals

The key traits that distinguish mammals from other vertebrates have many implications for how we get our food. These include homoiothermy (internal regulation of body temperature) and its consequences for metabolism; internal fertilization and gestation of offspring that are born live (though dependent) and nourished by maternal milk; and specialized types of teeth that process foods efficiently by different mechanical means (such as grinding, shearing, piercing, and crushing). Mammals can occupy a wide range of habitats because they are buffered from temperature extremes. However, warm-bloodedness has its costs in the form of increased energy requirements and a relatively high metabolic rate. Mammalian reproduction also places a heavy energetic burden on females, which must be able to feed themselves while nourishing the fetus (during gestation) and their immature offspring (after birth). Consequently, whether they are carnivores, herbivores, or omnivores, all mammals spend a significant amount of their waking hours pursuing, consuming, and digesting food. This is true whether the diet consists of low-quality, cellulose-rich grasses (necessitating multiple stomachs, bacterial fermentation, and hours of cud chewing) or muscle and fat that can be rapidly processed for extraction of nutrients. Because the mechanical demands of eating vary with the kind of tissue being ingested, mammalian jaws and teeth are morphologically diverse,

including extreme specializations such as the baleen filter-feeding of some whales and the complete absence of teeth in the giant anteater. However, the ancestral mammalian condition is heterodonty – different kinds of teeth coexisting in the same jaw. Although we will not witness a cow bringing down a deer with its canines or a lion spending hours grazing on the savannah, omnivory is a perfectly viable option for a mammalian lineage. Consider bears and raccoons, domestic dogs (who eat just about anything that people do), and of course *Homo sapiens*, the most omnivorous mammal of all.

Refinements of foraging strategies among the mammals are closely linked to a key innovation of the mammalian nervous system – the neocortex. This mat of interconnected cells is so extensive that it must be folded to fit into the cranium, creating the fissures and convolutions so pronounced in the human brain. The neocortex has important integrative and executive functions that allow for an unprecedented degree of behavioral complexity. The cognitive apparatus that underlies complex mammalian behavior, although still imperfectly understood, implies a powerful system of information processing that can be said to *know* something about the world. Mammals can take in information and process it in ways that allow them to fine-tune their behavior to the needs of the moment, within the constraints imposed by biological inheritance. Even the most specialized of mammalian diets – the giant panda’s focus on certain bamboo species being a well-known example – are pursued by lively and fluid minds. Mammals not only consume food; in certain respects, at least, they think about it.

As Primates

The human lineage belongs to one of the most ancient mammalian orders – Order Primates. The earliest primate fossils date to around fifty-five million years ago, but the number of living species suggests an even earlier date of origin – perhaps as early as seventy million years ago, during the time of the dinosaurs. These small arboreal insectivores, like other early mammals, carved out a nocturnal niche in ecosystems dominated by much larger vertebrates such as the dinosaurs. This initial set of adaptations diversified considerably following the major extinction event of the late Cretaceous period that wiped out the dinosaurs some sixty-five million years ago. The early primates that took advantage of this ecological void developed eventually into the tarsiers, lemurs,

monkeys, apes, and humans of the present day (as well as a number of extinct taxa). Primates have accordingly evolved an array of dietary adaptations ranging from nocturnal insect predation and specialized leaf eating to the eclectic omnivory of apes. Nevertheless, it is important not to lose sight of the fact that being a primate rather than some other sort of mammal entails certain constraints on the food quest.

Some of those constraints are historical in nature and hearken back to the original primate niche as arboreal insect-eating predators. Although this way of life has been largely abandoned by the so-called higher primates (monkeys, apes, and humans), its traces persist as part of our heritage. All primates have a high degree of manual dexterity that arises from keen visual perception coupled with precise motor control by a complex brain. Being a predator does seem to select for agility, speed, and intelligence, traits that have persisted in the primates regardless of their feeding adaptation. This heritage means that, regardless of their species-specific food preferences, primates are well positioned to be creative in the food quest.

OUR UNIQUE HERITAGE

As Hominins

The kinship of humans and the great apes – gorillas, chimpanzees, bonobos, and the orangutan – has been recognized widely since Charles Darwin's time (although it was famously resisted by biblical literalists and other advocates of human exceptionalism). Nineteenth-century scholars such as Darwin and Thomas Henry Huxley were quick to acknowledge the anatomical and behavioral similarities between humans and the great apes. Their observations of our near relatives, although necessarily limited in scope by the rarity of specimens available for close study, played a pivotal role in the argument for common ancestry of all living things – *Homo sapiens* not excepted.

The most recent common ancestor of humans and apes lived no later than five to seven million years ago, based on fossil and molecular evidence. Thereafter, this shared path diverged. A new and very strange sort of ape appeared – one that walked upright on its hind legs. These bipedal ancestors (and extinct cousins) of ours are the only other members of a distinctive group of primates of which humans are the only living representatives – the hominins (“Hominini” in [Figure 1.1](#)).²

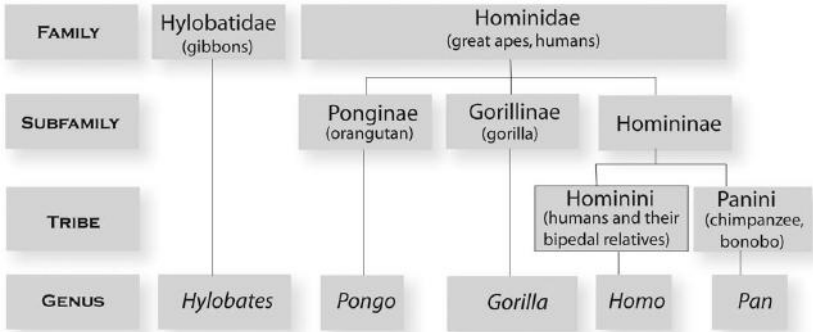


FIGURE 1.1. Chart showing the taxonomic relationships of humans and the great apes. Recent reinterpretations of the fossil and molecular evidence place humans and chimpanzees (including the bonobo) together in the same subfamily (Homininae). The term “hominin” (Tribe Hominini, outlined in black) is now widely used to designate humans and their now-extinct bipedal relatives, although some authors prefer the older term “hominid” for this group in accordance with more traditional taxonomies.

Upright locomotion, and all the anatomical specializations that make it possible, is perhaps the most important defining characteristic of the hominin clade. Why natural selection favored this mode of locomotion is not fully understood; however, its origin coincided with a period of fragmentation of forest into open woodland and savannah. The resulting changes in the types and distributions of resources is perhaps what made this rather unusual way of getting around on the landscape advantageous for some populations of apes.³ Whatever accounts for its origins, once established, bipedalism permitted hominins to investigate new sources of food. Bipedal locomotion is efficient and allows for a large foraging range, large enough to encounter a wide variety of potential foods. It also allows an individual to forage more efficiently while on the move by having two limbs available to pick fruit or harvest seeds. And although tool use is not precluded by being quadrupedal (as chimpanzee termite-fishing and nut-cracking demonstrate), it is certainly facilitated by the ability to use both hands at once whether one is standing or sitting.

Another key adaptation of hominins is a fluid behavioral repertoire that permits rapid adjustment to changing conditions of food availability. The success of the hominin lineage owes much to this ability to improvise, which was perhaps more fully realized by a bipedal and highly mobile animal than it could have been by one not so equipped.

Being a hominin, therefore, means innovating on the fly and having an unprecedented facility for making and using tools, whether you are an ancient hominin hacking apart an animal carcass or a world-class chef in a gleaming kitchen.

This responsiveness to the edible environment – enacted with tools for extracting a diverse array of resources, both animal and plant – is a defining characteristic of the human nutritional niche. The ability to innovate did not appear suddenly; rather, it developed gradually over several million years. But things began to change rapidly after two million years ago as seasonal climates became established. Hominins evolved bigger brains, more effective technology for capturing and preparing food, and a behavioral repertoire that could rapidly take advantage of elusive and hidden food sources that came and went with the seasons. It is during this period of time that the basic outlines of the human dietary pattern became established.

2

BEGINNINGS

In a very real sense our intellect, interests, emotions, and basic social life – all are evolutionary products of the success of the hunting adaptation.

Washburn and Lancaster, “The Evolution of Hunting”

Gathering food was an early, critical invention and an important step in the divergence of the hominid line.

Tanner and Zihlman, “Women in Evolution – Part I: Innovation and Selection in Human Origins”

Some five million years separate the elaborate traditions of *haute cuisine* from the opportunistic omnivory of the first hominins (our earliest ancestors who walked upright). This may seem like a long time, but in the context of the history of life on Earth, a million years is the blink of an eye. For complex animals that live long and mature slowly, years pass between the reproductive events that register the effects of natural selection. Genetic inheritance alone cannot account for the great diversity of human foodways observed today, although it goes a long way toward explaining why we are so adept at dietary improvisation. This tendency to innovate began to shape human diet long ago, in a world where the ability to explore new food sources had life-or-death consequences. But innovation alone cannot build traditions, accumulated bodies of knowledge about what and how to eat. Cultural traditions depend on cognitive capacities that allow people to share complex information. When this ability first developed cannot be known for certain; however, it may coincide with a significant expansion in brain size that occurred after one and a half million years ago with the emergence of *Homo ergaster*. Whereas many changes to dietary behavior were still to come, the basic anatomical, physiological, and mental adaptations that

shape our distinctively human relationships with food were already under construction.

The fossil and archaeological records that hold the evidence relevant to these momentous developments are frustratingly sparse, having been patchily distributed across the landscape to begin with, then suffering millions of years of weathering and disturbance. With so little to go on, anthropologists have enthusiastically mined a wide range of possible sources of relevant information. Speculative reconstructions of early hominin diet have been informed by observation of both modern hunter-gatherers and nonhuman primates that inhabit savannah environments. These analogs, being both closely related to the poorly known fossil forms of interest and living under similar environmental conditions, direct researchers to develop plausible models of early hominin dietary patterns. More direct evidence exists in the form of biochemical and anatomical features of modern humans that hearken back to ancient feeding adaptations of the hominin lineage. As we shall see, some of the fiercest debates about what our ancestors ate rage around topics for which we have very little direct evidence, such as the roles played by females and males in establishing the hominin dietary pattern. In the beginning there was speculation with a large ideological component supported by the most tentative of empirical underpinnings. More recently, ideology has been pushed aside in favor of multiple lines of scientific evidence based on new techniques of analysis – the microscopic study of wear patterns on teeth, the chemistry of bone, and cut marks on butchered carcasses.

THE AUSTRALOPITHECINES AND THEIR KIN

Our hominin ancestors represent an array of different species and even genera, but knowledge of behavioral differences between them is limited at present. Therefore, it seems justified to consider the most ancient well-documented species together as australopithecines, from the genus name given to the first fossil of the taxon discovered, *Australopithecus*. Australopithecines were relatively small brained compared to us, although well equipped with survival skills that included the manufacture of simple stone tools. Around two million years ago, this group gave rise to the human line, which is represented by fossil material assigned to the genus *Homo*.

The first australopithecine fossil discovered was that of a young child – a skull from the site of Taung in South Africa (see [Figure 2.1](#))

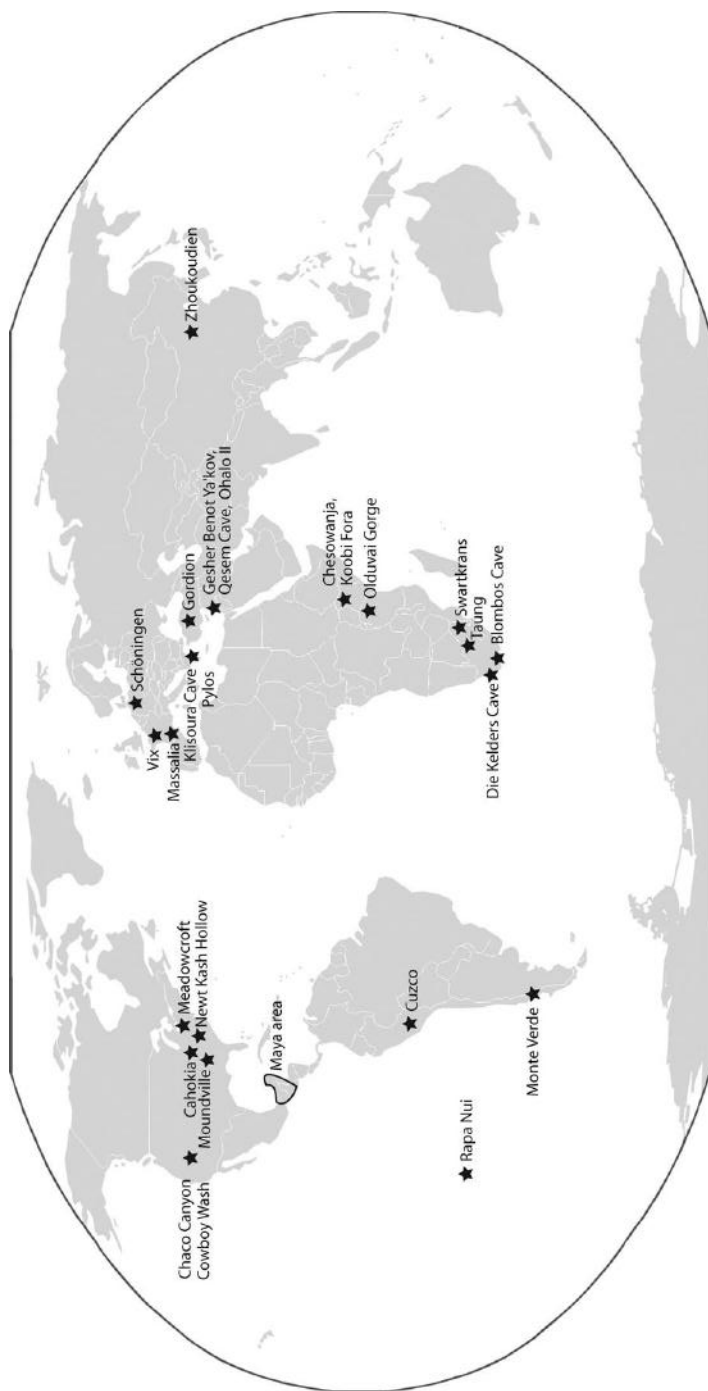


FIGURE 2.1. Archaeological sites and culture areas discussed in this book.

that was presented to the scientific community by Raymond Dart, one of the founding fathers of paleoanthropology. Dart famously speculated that the australopithecines were ferocious carnivores, using bone tools, teeth, and sharp nails to subdue and devour prey. There was little to support such an idea, however, aside from the fact that the South African fossils were usually found in limestone caverns mixed with the bones of many different species of mammals.¹

The Taung fossil was soon joined by other examples from East Africa, many of them collected and named by members of the famous Leakey family of Kenya. They, too, were finding australopithecines, as well as more humanlike fossils. Olduvai Gorge was a particularly rich source of the oldest known archaeological sites – accumulations of animal bones accompanied by stone artifacts made and used by hominins. The association of sharp-edged tools and remains of animals was suggestive of meat eating by later australopithecines or early *Homo*, but detailed reconstruction of diet remained elusive. Despite this somewhat enigmatic record, the question of meat eating remained central for paleoanthropology and set the tone for much of the research that was still to come.

MAN THE HUNTER, WOMAN THE GATHERER

One way of working around the difficulties presented by the material residues of subsistence activities was to switch to a different strategy entirely – that of developing plausible models of early hominin diet based on analogs whose behavior could be observed directly. Fuel for the analogic approach was provided by the surge in the anthropological study of hunter–gatherers – human populations who made a living by some combination of hunting, fishing, and collecting wild plant foods, without practicing crop cultivation or animal husbandry. Although a number of such societies had been studied by ethnographers (anthropologists who observe, describe, and analyze particular cultures), one group elicited especially keen interest among researchers in pursuit of early hominin behavior. This group of foragers came to be known to generations of students as the !Kung, although other ethnic names are used today for the speakers of San languages who occupy the Kalahari Desert of Namibia and Botswana. Their traditional way of life, today largely abandoned, was intensively studied; along with parallel studies of other hunter–gatherers, this research changed the way that anthropologists thought about small-scale, mobile societies.

What Richard Lee and his collaborators learned about the !Kung² was that it was possible for highly mobile people pursuing a hand-to-mouth existence to be well fed and healthy without working constantly at survival. Even in the harsh environment of the Kalahari, !Kung bands enjoyed considerable leisure time to socialize, dance, and simply hang out around the campfire mending tools or telling stories. Whereas the !Kung people are biologically no different from modern humans everywhere, they lived in an environment similar in certain key respects to that of the ancient hominins being scrutinized by paleoanthropologists. Pursuing the analogy allowed researchers to make plausible predictions – for example, that plant foods collected primarily by women provided the bulk of calories for early humans, whereas hunting by men offered key nutrients and had special social significance.

Although a strong case could be made by analogy for the importance of gathered foods in early hominin diet, it was hunting that anthropologists initially seized on as the key innovation of the evolving human lineage. In fact, some authors went so far as to place hunting at the core of human nature itself, as did Washburn and Lancaster in their landmark publication³ in the edited volume, *Man the Hunter*. They argued that herbivore populations on the African savannah tended to grow well beyond the ability of the environment to support them once hunting was outlawed, indicating that they must have formerly been kept in check by human predation. They pointed out that human males seem to have a propensity for violence and enjoy killing, and cited then-new observations of chimpanzees cooperatively hunting small animals. Washburn and Lancaster assumed, because of the absence of evidence at the time, that fish and shellfish only came into the human diet very late in prehistory, and that scavenging for meat was too dangerous and impractical. With the thinning of the forests, the only way for hominins to make a living was to become hunters – a radical innovation that demanded a new kind of social organization, one governed by cooperation between males who shared meat with their dependent mates.⁴

Direct evidence being as thin as it was at the time, a challenge to the “Man the Hunter” scenario was inevitable.⁵ In fact, there were several critiques that emerged from different quarters. It is understandable that feminist anthropologists weighed in with a model of their own, one that emphasized the role of female gatherers as movers and shakers in human evolution. These critics were armed with logic, analogies, and some very cogent points about Western assumptions regarding the nuclear family, female passivity, and the primacy of stone tools.

Why assume that hunting was the key to the human condition when plant foods, often collected by women and children, were obviously so important to the majority of extant hunter-gatherers? How could cooperation between males explain emerging social structures when the mother-infant bond formed the core unit of all primate societies? And why should we accept that the first tools were the chipped cobbles used to cut up carcasses, when perishable materials might have been used to dig tubers, “fish” for termites (as chimpanzees do today), or even fashion a sling for carrying an infant unable to cling to its mother’s fur? The pregnant mother and her immature offspring are particularly vulnerable to the winnowing effect of natural selection – nutrition, conservation of energy, and competent caregiving all weigh heavily in the evolutionary stakes of females. And perhaps a better option for females than depending on male hunters to provide them with meat was to become competent at using tools to extract some of the more refractory plant foods available, such as roots, seeds, and nuts.

Some researchers have argued that the ability to exploit a wide range of plant foods was just as important as meat eating for fostering key trends in human evolution, such as encephalization (increased size of the brain), changes in dentition, and even the sexual division of labor. A refinement of the “Woman the Gatherer” model⁶ proposes a key role for underground storage organs (USOs) such as bulbs and starchy roots. It is likely that edible roots, bulbs, and tubers became increasingly available in Africa, especially between 1.7 and 1.9 million years ago, coinciding with the first appearance of *Homo ergaster* and a dramatic shift to a drier and more seasonal climatic regime. Seasonality tends to promote the survival of plants that have mechanisms for buffering periodic stress by conserving energy when resources such as water are scarce. Underground storage organs are an excellent means of banking energy in the form of carbohydrates that can be mustered promptly to sponsor rapid growth when conditions improve. Appropriating this energy for themselves would have made good sense for hungry hominins, especially if they had the technological skills to recover and process deeply buried and somewhat indigestible plant parts.

Both hunting-centered and plant-based models have merits, and both are flawed. For historical reasons, the two models developed in opposition to each other, which led to a polarization in which the sexes seemed to be involved in some sort of contest to take credit for inventing humanity. Proponents of one view or the other run the risk of filling in the evidential void with cultural biases and political positions. However,

both of these models, and variants of them, have proven their worth by generating testable hypotheses and a great deal of profitable discussion among researchers. Models are part of the scientist's toolkit, having a special role to play in organizing and interpreting data in ways that move knowledge forward. However, models and theories have limited usefulness without evidence to inform them. Analogies are helpful, but they do not exhaust all the possibilities – and possibilities they must remain without being weighed against real-world data.

BONES, BUTCHERY, AND THE SCAVENGING HYPOTHESIS

During the 1970s and 1980s, when the debate over the relative importance of gathering and hunting was gaining momentum, there was virtually no evidence of plant use by early hominins. It is correct that this absence of evidence was not generally regarded as evidence of absence – organic materials just have a habit of quickly decomposing in most climates. The situation is somewhat different for remnants of animals, such as bones, which have the potential to be preserved for millions of years through drying or mineralization. When the right conditions exist, such bone accumulations are exposed or buried in deposits shallow enough to allow discovery. When they are found mingled with the crude stone tools used by early hominins, they reveal how meat may have been obtained, processed, and perhaps shared.

Fracture patterns and tool marks on bones provide unequivocal evidence that animal carcasses were being butchered. The tools found in association with bones of large mammals are generally classed as Oldowan, from Olduvai Gorge, where they were first recovered. The hallmark Oldowan tool is a cobble sharpened on one end to produce a rough edge for cutting. Other stones show signs of battering, as if they had been used to break open bones to obtain fat-rich marrow. Clearly these animals were on the hominin menu; there is no other reasonable explanation for the behaviors indicated by the “bone beds” of Olduvai and other African sites.

How these carcasses arrived at their resting place, however, is a separate issue and one that is trickier to investigate. If not hunting, then what? The scavenging hypothesis emerged as the chief alternative to the “Man the Hunter” model.⁷ After all, the African grasslands today are littered with carcass remnants left by top carnivores such as lions. After they have their fill, hyenas, wild dogs, carrion birds, and others take their turn at what remains: bones (some with marrow), scraps of

flesh, and perhaps some viscera. Perhaps early hominins created their own niche by scavenging such kills during the middle of the day, when most animals were resting. For this to be a successful strategy, however, there had to be enough nutritional value left in these carcasses to make their exploitation worthwhile. More might be gained by actively driving away carnivores and other scavengers and appropriating their kills while they were still meaty.

Whether or not a scavenging adaptation was feasible is a question that is still being debated. Relevant evidence continues to accumulate, but is not always easy to interpret as supportive of either hunting or scavenging. Instead, it is becoming apparent that meat acquisition by early hominins probably ranged along a continuum from passive versions (picking at long-abandoned kills) to more active ones, such as theft or hunting. Sometimes a sequence of behaviors can be deciphered from the order in which the bones were subjected to various actions, such as cutting, crushing, and gnawing by carnivores. The distinctive markings that characterize different treatments have been identified experimentally and the knowledge transferred to the interpretation of hominin butchering sites. Microscopic examination can detect which activity came first, as when cut marks are overlain by tooth marks. These studies show that in some cases at least, hominins had early access to the carcass, perhaps after predators had done some damage but before hyenas and other scavengers could fragment and disperse the bones. Further doubt is cast on the passive scavenger model by the fact that many sites preserve high frequencies of undamaged long bones – these prizes would surely have been cracked open by tool-using hominins who arrived at the kill too late to partake of the meatier parts of the carcass.

Our small-brained hominin ancestors may not have been sprinting across the plain, spears in hand; they were nonetheless active in the pursuit of game using a variety of strategies. Australopithecines probably preyed on small animals, much as chimpanzees do today. Larger game was certainly consumed, but in order for this to be a successful strategy, it must have involved early access to carcasses before predators or other scavengers could eat their fill.

A CLOSER LOOK AT THE FOSSIL RECORD

Like a crime scene, a site of butchering by early hominins offers analysts an opportunity to reconstruct, systematically and scientifically, the

events that created it. However, such re-creations are necessarily circumstantial. For direct evidence of what these hominins actually ate, we must turn to the nutritional equivalent of gunpowder residue: the traces of food and eating that become part of the body. For such ancient fossils, chemical and mechanical traces of this kind are rare, and when available, they are often difficult to interpret. Nonetheless, they are invaluable tools for documenting diet because they provide a record of actual consumption, not just the activities involved in obtaining and preparing food.⁸

We all carry in our bodies a record of what we eat. Substances that we ingest are broken down into more basic components, and these particles are then used to build and repair tissues, as well as being metabolized to yield energy. As animals, we take in large quantities of common organic elements, such as carbon and nitrogen. More important for the paleoanthropologist, however, are the rarer variants of elements that occur only as a minute percentage of the total found in the global environment. These isotopes differ from their more common versions only in the number of neutrons in their nuclei, but this minor variation is sufficient to cause them to behave differently in chemical reactions. Some isotopes are radioactive, such as carbon-14 (^{14}C), widely known as a dating tool. Others are stable (nonradioactive), among them the isotopes of carbon and nitrogen that have known concentrations in different food sources. Both isotopes and nonisotopic elements leave characteristic signatures as they are metabolized by organisms.

Studies of early hominin diet have relied heavily on ratios of strontium (Sr) to calcium (Ca). Diets rich in plant material build bones that have a high Sr/Ca ratio compared to those that emphasize animal foods. This means that the Sr/Ca ratio gets lower as we go up the food chain from primary producers (plants), to herbivores, and finally to the top carnivores that eat only other animals. Another indicator of diet is the stable isotope of carbon known as ^{13}C . The ratio of ^{12}C (the common garden variety carbon) to ^{13}C can vary greatly among the kinds of plants that form the base of the food chain. Plants, particularly grasses, that have adapted to arid conditions sometimes use a variant metabolic pathway that causes them to accumulate relatively high proportions of ^{13}C (confusing for the nonchemist, they are called C_4 plants for the number of carbon atoms produced at a crucial stage of photosynthesis). The same goes for animals that eat those C_4 plants and the predators that consume them, all the way up the food chain.

What these chemical profiles reveal is that early hominins relied heavily on plant foods, mostly seeds and tubers rather than fleshy fruits, with some insects and small animals mixed in. Teeth of South African australopithecines are relatively high in ^{13}C , suggesting a diet rich in drought-tolerant C_4 plants or the animals that eat them. It is estimated that these hominins got 25 to 35 percent of their calories from C_4 sources.⁹ Certainly this would make sense in the context of forest fragmentation and expansion of grasslands; C_3 plants, including most fruit-producing trees, were becoming harder to locate and farther apart. What kinds of foods are responsible for this C_4 -enriched diet? Grass seeds? Perhaps; however, grass grains are generally low-quality resources, meaning that they contain a great deal of indigestible fiber and, thus, have low nutritional value. There are some other possibilities, however. Many sedges, typically found in wetlands, are also C_4 plants and have nutritious tubers. Some small mammals, such as cane rats and hyraxes (rodent-like relatives of elephants), subsist mainly on C_4 plants, as do grasshoppers and many termites. Fishing for termites is something that chimpanzees do using bits of straw or sticks to coax them out of their nests, and australopithecines were capable of performing this task as well. None of these C_4 -enriched foods alone can account for the chemical profile of early hominin teeth, but in combination they certainly would. Australopithecines were branching out from a heavily fruit-based diet to one much more attuned to a varied landscape mosaic of dense forest, grasslands, woodlands, and wetlands.

The Sr/Ca ratio of South African australopithecines is also rather high, similar to that of grazers and carnivores on the African savannah today and much higher than that of browsers. This result seems to suggest that these hominins were eating grass or the herds of hoofed animals that fed on it. However, there are other foods consistent with the observed Sr/Ca ratios that provide a better fit with the general trend of primate diets and are well within the capabilities of animals with a rudimentary technology. These include insects and small mammals such as hyraxes, which also match nicely with the ^{13}C data. Underground storage organs also are enriched in strontium – although, being in most cases the product of C_3 plants, they diverge from the trend indicated by stable carbon isotopes.

These issues are not yet resolved, and isotope studies are still relatively new to paleoanthropology. However, it seems safe to say that there is nothing in the chemistry of australopithecine teeth that indicates

a meat-rich diet. Instead, the early hominin strategy was one that took advantage of a variety of habitats and food sources, rather than specializing in one or a few of them, setting the stage for the even greater versatility that was still to come.

While accumulating a chemical record of diet, teeth are also suffering wear and tear from chewing. When studied at the microscopic level, they show distinctive patterns of wear depending on the type of foods eaten. The silica particles in grasses carve out grooves in the enamel, leaves produce scratches, and fruits cause pitting. Tooth wear in australopithecines indicates a diet of seeds and soft fruits initially, with the addition of more brittle or tough foods as diets became more varied. The surface of hominin teeth, thus, tells the same story as the molecules within them, one of being versatile enough to rewrite the menu to utilize the available ingredients.¹⁰

HISTORY IN THE BODY: EVOLUTIONARY ANATOMY AND MOLECULAR MARKERS

If form follows function, then teeth should be designed by natural selection to do some jobs better than others. Although we cannot always predict function from form, the shapes and sizes of teeth (or any other body part) reflect what roles they had to perform during an animal's history. For instance, the initial trend in the hominin lineage (among australopithecines and early *Homo*) is in the direction of thicker enamel, a trait that prevents teeth from cracking and allows them to last longer under stress. Building extra enamel costs energy, so it must have had some benefit, which in this case probably was to combat dental attrition as hard and brittle foods entered the diet. The large, flat molars of australopithecines and their rather small incisors were not very useful for tearing tough, pliant foods such as meat and some types of fruit husks, but were well suited to crushing hard foods. Grass seeds and USOs are more likely targets for this kind of dentition, which is consistent with tooth wear and tooth chemistry. With *Homo*, the genus to which we belong, jaws became smaller and less robust, and thinner enamel made it easier to process tough foods. The trend to smaller teeth and jaws was to continue as technology took on more and more of the work involved in preparing food to be absorbed by the body.¹¹

The rest of the digestive apparatus in modern humans is capable of processing a wide range of foods, including meat. Overall, the human gut is relatively small in relation to body size, which means it is not well

equipped to process large quantities of bulky, low-quality foods such as leaves; on the other hand, we do not have the very short digestive tracts of true carnivores.¹² The small intestine makes up a larger proportion of the total gut – some 56 percent – than it does in extant apes such as the gorilla and chimpanzee. Our food spends much of its time there, being absorbed, rather than in the stomach, being broken down by acids and microorganisms. This is why humans have a ribcage that tapers at the bottom, rather than expanding as it does in apes to accommodate frequent consumption of hard-to-process foods. This change in the shape of the belly seems to have taken place around the same time that our ancestors were expanding their dietary repertoire to include more hunted or scavenged meat, using tools to make this task more efficient.

A smaller gut creates an opportunity for an energy-hungry organ – such as the brain – to expand. Brains are costly to grow and maintain, and a large and active one needs to be fed, preferably with food of high quality. Meat and especially fat fit the bill. Meat is calorie-rich, easily digested, and provides proteins and macronutrients needed for the brain to grow. Certain fatty acids, which infants get from breast milk, are particularly crucial for developing and maintaining a large brain. In contrast, leaves and other fibrous plant parts – low-quality foods – require extended bouts of feeding and digesting that take time away from other activities like socializing and exploring the environment. Thus, it seems likely that animal foods, along with nutrient-rich plant foods, played an important role in fueling the great leap in brain size that took place after two million years ago in the human line.

All the evidence, direct and indirect, for the eating habits of ancient humans converges on a single theme: adaptability.¹³ Dietary versatility seems to have been the key to hominin success rather than adoption of any specific food, although animal foods became increasingly important after about two million years ago. The last common ancestor of humans and chimpanzees had the ability to capture and eat animal prey; hominins simply expanded on this ability by finding new and better means of doing it. These methods probably included scavenging of carnivore kills, perhaps aggressively, and some hunting. The form that hunting might have taken is unknown because no hunting weapons are in evidence at this early period; stone tools were designed for extracting meat and marrow from dead animals, not for capturing live ones. There were almost certainly tools of more ephemeral materials such as bone and wood that were used for tasks like termite fishing, digging

up tubers, crushing nuts, and killing prey or driving away predators.¹⁴ More regular consumption of animal foods had lasting effects on the human body, molding it into an efficient system for processing a wide variety of foods, including meat.

There was more to the shaping of human food habits than discovering the merits of meat, however. The chemistry of bones and especially teeth indicate a diet rich in plant foods, probably including roots and tubers and grass seeds as well as the primate staple, soft fruits. Trace elements also point to consumption of invertebrate animals, particularly insects (a survey of contemporary culinary traditions will show that the Western squeamishness about eating these creatures is not widespread). A mixed diet is also evident in the structure and wear patterns of teeth, which were used to crush seeds and chew soft fruits and were not very effective for tearing meat or tough, leathery fruit skins (at least not until after two million years ago).

The development of these very flexible and diverse means of getting food, driven by a complex brain and versatile behavioral repertoire, mark a turning point in human evolution. This shift makes more sense as researchers learn about the environment in which hominins first arose and diversified.¹⁵ The climatic trends that came into play, particularly after two million years ago, created conditions that favored the ability to improvise. The general drying trend that has long been recognized as an influence on human evolution also included a component of unpredictability and periodicity, introducing seasonal cycles as well as irregular fluctuations in rainfall and temperature. New resources became available as customary ones became less reliable and more scattered across the landscape. These environmental changes, in conjunction with the unique history of the hominin line, led our ancestors along a trajectory from bipedal apes to culinary adepts able to transform a diverse array of organisms into food. An important threshold of dietary diversity was crossed when hominins began to transform food through the controlled use of fire. Afterward, human diets would never be the same.

COOKING

For millions of years, our ancestors ate food more or less as they found it. They used tools to extract it and moved it around from place to place without venturing into the complex alchemy of cooking.¹⁶ In contrast, today it is hard to imagine human society without its diverse

culinary traditions.¹⁷ Most of us take the practice of food preparation for granted and would feel impoverished in a world of raw, unseasoned, plain fare. We are no longer anatomically well equipped for eating unprocessed food (although raw food enthusiasts insist that it is better for our health). We have come to rely on cooking, pounding, grinding, and other techniques to predigest our food, breaking it down into more digestible constituents before it reaches the mouth. Food preparation serves symbolic as well as biological functions, conveying messages about status, gender, wealth, and the supernatural.

When the transition from raw to cooked food began is not known. Most of the tools used to process plant foods, such as grinding stones and cooking pots, appear late in prehistory (after 40,000 years ago) and are associated with fully modern humans. For earlier periods, anthropologists rely on the occasional tool and evidence for the control of fire, which is often difficult to interpret. But even without being able to pinpoint the origin of cooking, it is possible to appreciate its significance in human history.

Whereas the intricate interplay of human biology, food technology, and culture has today become enormously complex, food processing probably owes its origin to a rather straightforward set of functional considerations. Most of these have to do with the relative indigestibility of many plant foods.¹⁸ Nutrients can be locked up in stable compounds that stubbornly resist digestive enzymes – for instance the lignins that give wood its hardness, and cellulose, the stuff of cell walls. Besides being non-nutritive, such indigestible fiber speeds up passage of food through the gut, leaving less time for nutrient absorption. Many plants in the wild also contain chemicals that are toxic to mammals, or at least unpalatable. Plants usually have little to gain by being eaten. There are exceptions, usually involving the dispersal of seeds by animals that eat and excrete them some distance from the parent plant. Without such a reward, however, plants that neglect to defend themselves from predators leave fewer offspring than those that discourage predation by tasting bad, being downright poisonous, or containing crystals that are painful to ingest. These defensive adaptations of plants go a long way toward explaining why humans devote so much time and energy to modifying plants before eating them. Even meat, which is easily digested, can be improved by cooking if it is contaminated by disease-causing microorganisms. Overcoming these obstacles to produce a better quantity and quality of foods may well have given our ancestors a competitive edge over their less innovative cousins.

Breaking Down the Barriers

Cooking methods tend to sort into two broad categories: those that mechanically break down structures that interfere with absorption of nutrients, and those that act at the molecular level to change or remove problematic chemicals. Mechanical methods include grinding, pounding, winnowing, chopping – whatever it takes to make nutrients more accessible to the body. Grinding and pounding increase the surface area of the particles to be consumed. Winnowing uses wind and gravity to carry away indigestible parts such as the “chaff” on grains (a mixture of leaflike bracts, stalks, and residual flower parts). Chemical techniques are quite varied. Many of them involve heating, which can be either wet (boiling, steaming) or dry (roasting, smoking). This is the kind of preparation that most people think of as cooking, but there is more. Consider other kinds of chemical alteration, such as fermentation, which uses microorganisms to break chemical bonds and remove toxins. Soaking can leach out toxins, with or without heat. Additives are often used to change the acidity of foodstuffs, or bind to and neutralize undesired chemicals.

Although cooking sometimes lowers the nutritional value of foods by removing vitamins and destroying proteins, the benefits greatly outweigh the costs in most cases. The overarching benefit of cooking is that it acts as a kind of predigestion that extends the human body’s ability to extract nutrients efficiently, greatly increasing our ability to adapt to changing circumstances. We need not rely on natural selection to winnow out genes that are responsible for a poor fit with new conditions. Instead, we use technology to process food according to the needs of the moment and store up what we learn in the form of tradition. The resulting body of knowledge represents the most successful innovations, refined by experience and accumulated over generations.

TOXIC TUBERS AND CHANGING CLIMATES. With these benefits of cooking in mind, let us return to the USOs likely to have been targeted by *Homo ergaster* and other hominins in Africa in the increasingly seasonal habitats they occupied after two million years ago. These starchy organs are a boon for plants that must survive the dry season in a dormant state and then grow rapidly when the rains come. Unfortunately – at least for the plants – storage organs are also attractive to animals, being rich sources of carbohydrates. As predators refine their attack strategies, plants evolve ever more effective defenses. To make matters worse

for hungry hominins, USOs can be very difficult to extract. Human foragers may spend hours wielding a digging stick to unearth a tuber of impressive size. The effort may be worthwhile for modern people, who can roast, boil, or soak even a tough and fibrous tuber into palatability. But did *Homo ergaster* have this option?

In a word, maybe. Some tantalizing evidence of burning in association with hominin activity exists at very early African sites. However, these early examples only hint at control of fire; they do not demonstrate it, much less provide us with solid evidence of cooking. There is Swartkrans, a famous South African australopithecine site, which has yielded burned nonhominin animal bones dating to between 1.0 and 1.5 million years ago. The bones show traits that are consistent with experimental burning in hearth fires, but are also compatible with natural burning. At Koobi Fora in Kenya, burned areas associated with hominin activity around 1.6 million years ago were carefully analyzed using a variety of methods; investigators concluded that the fires responsible for burning were probably controlled, but were not used for cooking. Burned clay recovered from Chesowanja in Kenya was heated at temperatures comparable to those created by a campfire but this is very different from being able to say that they were, in fact, created in this way. None of these cases are widely acknowledged as firm evidence of hominin control of fire; this is so because the alternative interpretation of naturally occurring fires cannot be ruled out. Such caution is normal scientific practice when a discovery appears to be inconsistent with a large body of existing knowledge. We will just have to live with the ambiguity imposed by the incompleteness of the archaeological record for the control of fire and hope that future discoveries will enlighten us.

Assuming that they could not effectively create or maintain fire, or at least did not use fire for cooking, is it feasible that the earliest humans expanded their plant food repertoire to include underground plant parts? This venture into novel foods would have been facilitated by heating to remove toxins and release nutrients, allowing humans to explore a wider range of plant foods than ever before. However, there are alternatives to heat treatment that would have made at least some of these nutritious resources available. There is the option of no treatment at all; roughly half of edible roots and tubers surveyed on the present-day African savannah can be eaten by humans raw without ill effects. Some of the plant chemicals ingested may have had health benefits of some kind, such as discouraging or expelling internal parasites. Whether diet could have been diversified enough without cooking

to improve survival and reproductive rates for hominins is difficult to assess.

It is also important to remember that cooking, as defined here, need not require the control of fire, or even high temperatures. Geophagy – eating soil – can be an effective way of detoxifying plant parts if the two are eaten together so that the clays can bind with the toxins and render them harmless. This practice does not depend on elaborate technology and has been observed in nonhuman primates (although USOs are not popular with most species).

Fire

Evidence of controlled fire prior to one million years ago – and most of that predating 300,000 years ago or so – is controversial. As we approach the present, evidence becomes both more available and more convincing. This trend may be at least to some degree a result of the greater chance of more recent materials surviving. There are, thus, more opportunities to observe the telltale signs of a human-controlled fire. Although many measurable traits – temperature of the fire, presence of charred bones or seeds, burned flint – suggest that humans were involved, most of them fall short of allowing researchers to exclude natural fire as a possibility.¹⁹

The site of Zhoukoudien in China, long considered the earliest solid evidence for fire control at 300,000–600,000 thousand years ago, has been reevaluated. As a result, the “hearths” discovered there were found to be devoid of ash and charcoal – a definite strike against the presence of campfires, despite the burned bones and stone tools. There are some very promising early sites in Israel, however. At Qesem Cave, archaic humans gathered around a fire to butcher deer and reused the same spot many times between 400,000 and 200,000 years ago.²⁰ The site contains a buildup of wood ash cemented by repeated heating – a signature that could not have been produced by natural fires. Bone fragments show signs of having been heated either briefly at high temperatures or at lower temperatures for longer periods of time, another pattern unlikely to occur outside of a campfire. Even more impressive in terms of the quality of preservation is Gesher Benot Ya’aqov, a waterlogged site dating to around 800,000 years ago. Waterlogging is a condition in which objects become saturated with water in the absence of oxygen, which excludes life-forms such as bacteria and fungi that consume organic material. As a result, waterlogged sites preserve seeds, fruits,

wood, leather, textiles – in brief, just about every kind of organic artifact or food remain that decays rapidly in oxygen-rich environments (although bone is often lost to high acidity). At Gesher Benot Ya'aqov, waterlogged conditions preserved a multitude of seeds and fruits that may be remnants of meals. There are no formed hearths, however, just areas of concentrated burned flint artifacts. Apparently, not long after one million years ago, ancient humans warmed themselves around the fire made from the wood of wild olive and Syrian ash trees. Whether they cooked their food is uncertain; most of the 20,000 fruits recovered from the site were not charred.

It is not until after 100,000 years ago that there are incontestable indications of formed hearths (although the practice may well have begun earlier). Hearths come in various shapes and sizes and may be simple or complex, but they all share the feature of being defined and sometimes confined to places where sustained fires were allowed to burn. By and large, hearths are a product of anatomically and behaviorally modern humans (although our Neanderthal cousins made them as well). After 100,000 years ago, our ancestors were people not very different from us in the makeup and functioning of their brains and bodies, so it should not be surprising that they sat around campfires cooking, socializing, telling stories, and staying warm.

Archaeological signals of cooking and other forms of food preparation are one material expression of a far-reaching transformation in human thought and behavior that becomes increasingly visible in the archaeological record after 100,000 years ago. Viewing the archaeological record of the past 100,000 years, it is possible for the first time to recognize many of the traits that we see as being quintessentially human. Ethnic identities, personal adornment, complex beliefs about the supernatural, and formal burial of the dead make their first appearance during this interval. Technology of all kinds, including tools and strategies for capturing, processing, storing, and consuming food, made great strides in complexity, efficiency, and diversity. These momentous changes were not instantaneous, but they were remarkably rapid by the standards of evolutionary biology. This rapid pace was the product of a complicated synergy between biological inheritance, behavioral improvisation, and cultural tradition.

Archaeology cannot tell us when culture – cumulative social learning – became the *sine qua non* of human existence. However, we can confidently attribute to this unique knowledge system the next great transition in human foodways. The new era was one of innovation in

many guises, but these new ways of acquiring and consuming food began to cohere into regional traditions closely attuned to time and place. It is with these developments, owned and operated by fully modern people, that a recognizably and uniquely human way of relating to food begins to emerge.

3

FORAGING

Man falls upon everything that comes in his way; not the smallest fruit or excrescence of the earth, scarce a berry or a mushroom can escape him.

Joseph Addison, in *The Spectator*

The pace of change in human foodways picked up considerably after 100,000 years ago. Whereas some of these innovations in food technology had predecessors in earlier millennia, many did not; those that did have a history were elaborated, diversified, and improved. Many, if not all, of these new ways of acquiring and processing food originated with fully modern people who had essentially the same anatomy, physiology, and cognitive capabilities as we do. The apparent novelty of some behaviors is no doubt an illusion created by the increasing visibility and preservation of material remnants of human activities, but that is not the whole story. Instead, the record as we know it reflects a real and significant shift in the way humans related to the natural world and to each other.

THE UPPER PALEOLITHIC REVOLUTION?

Since the nineteenth century, archaeologists working in Europe were keenly aware of the contrasts between the habitations and tool traditions of modern people (then known as “Cro-Magnons”) and the Neanderthals, archaic humans whose behavioral repertoire seemed quite limited in comparison. The Cro-Magnons seemed more like modern humans. Their toolkits were extensive and specialized; they hunted migratory game, fished, sewed, and built shelters. In contrast, Neanderthals were not only physically distinctive with their short stature,

robust physique, and heavily muscled skeleton; they also appeared to lack many of the artifacts and behavioral attributes of more modern-looking people. The two human variants overlapped in time, with the modern humans of the Upper Paleolithic period in Europe largely replacing Neanderthals between 40,000 and 30,000 years ago.¹

Modern anthropology has rehabilitated Neanderthals, and current interpretations have been revised in accord with new evidence from archaeological sites, skeletons, and ancient DNA. We now have evidence that Neanderthals used plant foods, hunted some large game, and perhaps did some other things that anthropologists used to reserve for fully modern humans. DNA evidence, in contrast, has tended to reinforce the distinctiveness of Neanderthals and the low probability of their being our ancestors.² While the debate continues over the magnitude, character, and origin of behavioral differences between archaic humans such as Neanderthals and “behaviorally modern” *Homo sapiens*, we can afford to be comfortable with the conclusion that, by no later than 30,000 years ago, humans worldwide were linguistically competent and cognitively sophisticated. They made long-range plans, honored their dead, wore ornaments, played musical instruments, and created art depicting humans and animals in different media. These were skilled foragers who were able to closely track resources, adjusting their methods and tools to suit local conditions.

Where did this novel behavioral repertoire come from? Neanderthals may have shared in and contributed to the suite of traits we think of as modern, but they were not its ultimate source. Neanderthal ancestry also does not quite square with the distribution of genetic variation in modern populations. It turns out that all of us alive today are descended from a single population that lived in Africa some 150,000 to 200,000 years ago. This date is an estimate based on the mutation rates of mitochondrial DNA (mtDNA), a specific sort of DNA that is handed down from mother to daughter, but is also supported by fossil and archaeological evidence that has emerged since the first mtDNA studies. The implications of such recent common ancestry are profound: The archaic humans that colonized parts of Europe and Asia from Africa beginning just after one million years ago were ultimately unsuccessful, making little if any contribution to the contemporary human gene pool. They were largely replaced by the new kind of human that spread from an African homeland after 100,000 years ago to eventually colonize most of the Earth’s habitats.³

Although cultural transmission moves on many paths, not just from parent to child, genes and behavior often travel together. We should, therefore, expect a fairly cozy relationship between anatomically modern people and the whole package of behavioral and cognitive traits that characterize modern humans, particularly if these innovations were linked to changes in the function or organization of the brain. However, a large chronological gap seemed at first to separate people who looked like us and those who both looked *and* behaved like us. The gap has narrowed as recent research has brought to light a richer material record of the first modern humans in Africa, which contains glimmerings of the impressive artistic and technological achievements of the European Upper Paleolithic some 60,000 years later. The Upper Paleolithic revolution was, in fact, neither of those things – it germinated in Middle Stone Age Africa and developed over tens of thousands of years before the diaspora that brought modern humans to Europe and eventually the rest of the world.

That diaspora began sometime after 100,000 years ago; by 30,000 years ago, modern people had largely replaced their archaic predecessors (although exchange of genes and information between these populations cannot be ruled out). Modern people possessed a suite of survival skills that allowed them eventually to colonize nearly every habitat on Earth. They left a rich record of their pursuit of game and plant foods: they hunted with bows and arrows, pounded nuts and seeds into meal, made nets and snares and fishhooks. Innovation is obviously at work here, fueling technological change at an unprecedented rate. However, invention alone could not account for the diversity of regional foodways that was to develop as modern humans spread throughout the globe. Their competitive edge was grounded just as firmly in the ability to transfer the products of innovation to subsequent generations, using sophisticated symbolic communication – what we call language. Together, invention and tradition merged to create a unique, species-specific way of surviving.

This system of social learning explains diversity of human foodways just as biological evolution provides the baseline of nutritional needs, food preferences, and range of possible behaviors. Too much flexibility is not necessarily a good thing, because it is inefficient for each generation to learn about food on its own without instinct or tradition as a guide. This is true especially if the environment remains stable; in that case, it is more efficient to inherit some of the relevant

information, culturally as well as genetically. You learn nut cracking at your grandmother's knee, and teach your grandchildren the same. Social learning saves time and effort. Should the trees give way to grassland in the future, though, your descendants need not starve, because they have the intelligence to invent new techniques based on the old. Culture is an optimal way to combine and balance the benefits of innovation and tradition, invention and inheritance. It was an adaptation that was to prove enormously successful in the changeable and unpredictable world of the Late Pleistocene, the last gasp of the Earth's most recent ice age.

THE LATE PLEISTOCENE WORLD

The natural world in which modern people honed their survival skills would seem alien to us in many ways. Most of human evolution took place during the geological epoch called the Pleistocene, which lasted from 2.6 million years ago to roughly 10,000 years ago ([Figure 3.1](#)). Though sometimes referred to as the "Ice Age," this label is somewhat misleading in that it glosses over this era's most salient characteristic as far as people are concerned: its variability. Far from being a monolithic span of unrelenting cold, the Pleistocene was marked by warm intervals separating periods during which glaciers advanced under the influence of persistently low temperatures. And although frigid conditions characterized higher latitudes situated close to the ice, the tropics were often more affected by fluctuating rainfall than by changes in temperature.

The dispersal of modern humans from Africa took place during the last major glacial cycle, which began around 120,000 years ago as the oceans cooled and ice sheets grew across the northern continental land masses. The cold period peaked around 18,000 years ago, followed by an unsteady transition to the climatic regime known as the Holocene about 10,000 years ago. This general trend has held up under the flood of paleoclimatic data that has accumulated over the last decade, but we now know that it masks considerable variability. The cooling trend of the last glaciation was interrupted by numerous brief periods of warmer temperatures and accentuated by several unusually cold episodes. So whereas northern latitudes were indeed cold during the later Pleistocene, they were not consistently so. In fact, extreme variability in temperature and related aspects of the natural environment had its own unique role to play in shaping human adaptations during this volatile period.

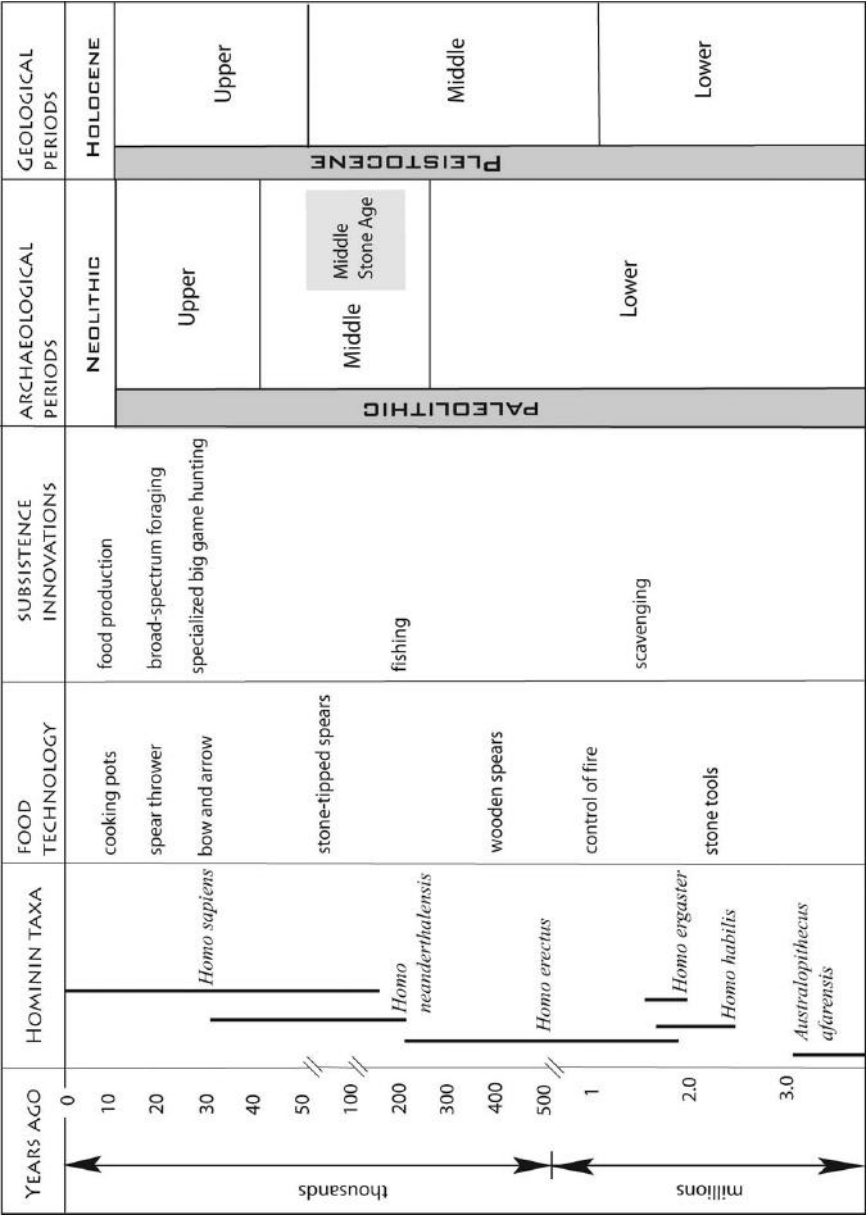


FIGURE 3.1. Comparative chart showing archaeological and geological periods and associated developments in food acquisition and food technology.

To understand the impact of severe and rapid climatic fluctuations on human societies, it might help to consider them in relation to the span of an individual's lifetime. Without the permanency of written records, the transmission of culture – how to hunt, harvest seeds and tubers, catch fish, as well as all the rest of the lore that helps people survive – depends on the capacity of human memory. Your grandfather learned to hunt from his male relatives, and you benefit from his knowledge of how to make a good spear or fashion and place snares for small game. This knowledge will stand you in good stead for years to come, even if you experience somewhat heavier snowfalls than your grandfather did, or more frequent droughts. But consider a change in average temperature of 18°F (10°C) over a single decade (an increase in temperature of this magnitude marked the end of the Younger Dryas, the final burst of cold at the Pleistocene/Holocene transition).⁴ Even the world your father learned to hunt in has effectively vanished; he learned to track animals in the snow, but now you must improvise.

Under these conditions of rapid change and readjustment, the flexible system of cultural transmission has significant advantages over ordinary natural selection of genetic variation (whose pace depends on generation time). Unlike genetic information, cultural knowledge can be shared rapidly between unrelated individuals. Culture represents the accumulated knowledge of many generations, whereas improvisation alone is prohibitively expensive, requiring much time spent learning from experience, and suffering from the inevitable setbacks of trial and error. Cultural transmission is an effective substitute for individual learning when conditions are stable across generations, but it also permits innovation to step in when inherited information about the environment becomes obsolete. Such a system would have given the humans who possessed it a significant competitive advantage in a changeable world.

NEW TOOLS, NEW TACTICS: THE FOOD QUEST IN THE LATE PLEISTOCENE

Some of the most striking differences between fully modern humans and their predecessors are those that indicate new ways of thinking about the natural and social worlds. Art, personal ornamentation, ritual behavior (and inferred belief in the supernatural) all signal the attribution of meaning to people, animals, and objects. Whatever the source of this cognitive shift, it had implications for the mundane tasks involved in

the food quest. The improved methods for obtaining and preparing food that emerged in the Late Pleistocene, although they built on earlier technologies, seem to bear the hallmarks of the new mind: a reliance on symbolic communication to share and accumulate knowledge and a penchant for innovation in the face of changing conditions.

Technology

HUNTING. It makes sense to assume that hominins hunted at least occasionally from earliest times; the fact that chimpanzees hunt smaller animals means that this behavior was most likely present in the last common ancestor of humans and chimpanzees, just before hominins emerged as a distinct branch on the primate tree. However, the technology of hunting by the earliest hominins is largely invisible – if, indeed, such technology existed. Tools are not required for hunting small game and may have been limited initially to the stone flakes and choppers used for cutting up carcasses. Of course stone is only one possible raw material for hunting weapons, and australopithecines and early *Homo* may have used perishable wood or bone to injure and kill their prey.

The earliest solid evidence of hunting weapons comes from the site of Schöningen in Germany (Figure 2.1) and consists of several spears made from spruce wood. Their survival following some 400,000 years of burial is a happy accident of preservation by waterlogged conditions that prevented the growth of microorganisms. The Schöningen spears are considered by their excavator to have been thrown at animals from a distance, judging from their weight and balance, which resemble that of historical javelins.⁵ If they were in fact used in this way, they offered significant advantages over stabbing, which requires the hunter to get very close to a large and often angry animal.

The gap between Schöningen and the first archaeological indications of hafted weapons, such as stone-tipped spears, stretches nearly to the present day. Modern humans living in southern Africa were making spears with small, sharp stone tips bound onto a shaft with twine as early as 60,000 years ago,⁶ although stone-tipped projectiles only became widespread in Africa, Europe, and the Mideast after 40,000 years ago.⁷ Sometimes they used pointed bits of bone rather than stone, but the principle was the same: to hurl the weapon from a safe distance. In contrast, Neanderthal people in Europe and the Mideast are thought to have relied on getting as close as possible and then stabbing their

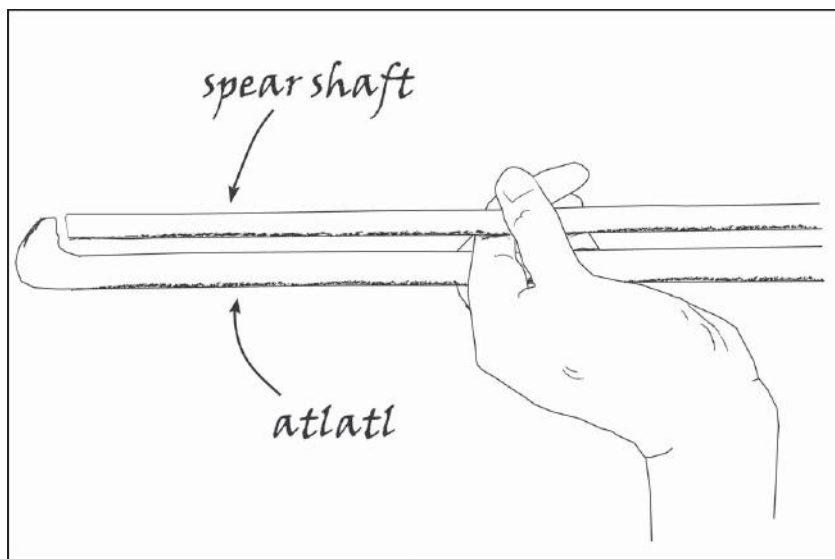


FIGURE 3.2. Method of using the spear thrower (atlatl). The atlatl acts as an extension of the human arm, increasing the distance and force of the weapon.

prey – a strategy that may account for the high rate of traumatic injuries in Neanderthal skeletons, compared to those of modern humans.⁸

Thrown spears have distinct advantages over the stabbing technique, but there is an even better way to throw a spear than to launch it simply by hand. A relatively recent improvement to this way of hunting was the spear-thrower or *atlatl*. This device acts as an extension of the arm. The butt end of the spear is fitted into a socket attached to a second shaft held by the hunter (Figure 3.2). When launched, the spear is propelled farther than it could be without the spear-thrower, extending the range of the device. Spear throwers appear in the archaeological record of western Europe around 20,000 years ago, represented by elaborately decorated bone or ivory weights that were placed on the spear thrower itself to balance it.⁹

Another quantum leap in hunting technology came with the development of the bow. Some of the small, sharp points found at sites in east Africa and dated to 65,000–70,000 years ago were probably used to tip arrows rather than spears, based on their size and shape.¹⁰ The bow came to largely replace the spear as the weapon of choice, although it would be surprising if the older technology were not kept around for at least occasional use. Spears work well over open ground such as



FIGURE 3.3. Depiction of a bison from the cave of Altamira in Spain (photograph of a reproduction of the cave ceiling at the Brno Museum).

tundra, provided the hunter can find enough cover to get close enough for a good shot. In forests, however, the bow was superior for its ability to launch projectiles through the thick vegetation that began to spread across many landscapes during the Late Pleistocene along with warmer temperatures. In fact, the bow was more effective over a wide range of environments because it allowed the hunter to shoot quickly from a variety of positions, to aim along the arrow's shaft, and to carry plenty of ammunition (tipped arrows or just the points).¹¹

People seem to have become more effective hunters over time, based on their technology. However, rather than representing a one-way steady ascent to greater and greater expertise, the trajectory of hunting technology was always responsive to the environmental conditions in which humans had to survive. Hunting in general became a major source of calories during periods of glacial advance, when cold winter temperatures and snow cover made large animals the only game in town. The centrality of these large herbivores – horses, wild cattle, reindeer, and others – can be seen clearly in the cave art of Upper Paleolithic France and Spain (Figure 3.3). The assemblages of animal bones from

many European Late Pleistocene sites suggest a way of making a living similar in some respects to that of more recent Arctic hunters, who rely on animal tissues for most of their calories. We can assume that meat and fat were supplemented by plant foods, but these would have been short-lived summer phenomena in a tundra habitat and insufficient to support a group of foragers. In contrast, the migrating herds of reindeer offered large packages of meat, hides, and other useful parts.

One source of calories makes its initial appearance in cultural contexts during the last 100,000 years: fish and shellfish. Abundant fish bones first show up at archaeological sites in southern Africa, such as the Middle Stone Age levels at Blombos Cave (Figure 2.1), which contained accumulations of bones and shells from a wide variety of both land and aquatic creatures. Blombos yielded some ten varieties of fish and many types of marine mollusks dating to around 70,000 years ago. Fishing harpoons of similar age have been recovered from Zaire; nets are in evidence only about 30,000 years ago, during the European Upper Paleolithic. In contrast, there is only sparse evidence of seafood use among Neanderthals and their kin, or earlier hominins.¹²

In addition to incorporating new sources of nutrition, human foragers seem to have changed their strategies by selecting more challenging prey. A bias toward adult ungulates (hoofed animals) in their prime can be seen in the demographic profiles of animal bone assemblages as early as 250,000 years ago, but this trend became well established only in the Late Pleistocene.¹³ This is an interesting fact because prime-age adults entail higher costs than young or old animals, although they also yield greater returns. Earlier human hunters tended to focus their efforts on the more vulnerable members of a herd, which may reflect limitations imposed by the kind of hunting weapons and strategies available at the time. At some of the South African sites, there is a similar trend of people putting more effort into capturing dangerous large animals, such as water buffalo, as compared to the less menacing – and smaller – eland.¹⁴

PLANT FOOD PROCESSING. Remnants of plant foods are poorly represented at Pleistocene sites because they tend to deteriorate rapidly, even when preserved through charring. We assume their importance to early humans nonetheless, based on the basic primate and ape dietary templates; however, details remain sparse until the Late Pleistocene. Most of these details come from sites with exceptional preservation of seeds and other plant parts as well as more durable artifacts. The evidence from

such sites is changing the way archaeologists think about the evolution of cooking technology.

Early cooking was limited to basic methods that did not require containers. Meat and plant foods alike can be buried in earth ovens or simply roasted directly in the fire. This style of cooking probably accounts for the clay-lined hearths unearthed at Klisoura Cave in Greece, which date to 26,000 years ago.¹⁵ Contents of these hearths contained burned bones and seeds, which are suggestive of cooking over an open fire. The hearth ashes also contain some much smaller remnants of plants, in the form of phytoliths (literally “plant stones”), which are microscopic particles of silicon dioxide that often preserve the form of the plant cells in which they accumulate. Abundant grass grain phytoliths found in the Klisoura hearths are mixed in with the ash, a strong indicator that people roasted or parched edible seeds.

The people of Ohalo II, a remarkable waterlogged site in Israel that dates to around 23,000 years ago, took seed processing a step further – they ground grass seeds into meal using massive stones.¹⁶ Although the women who most likely prepared the grains were not farmers, they anticipated a technology that was to be essential to the success of cereals such as barley and wheat as staple foods. And they did not process just any wild grasses in this way; the starch grains that hide within the pores of the Ohalo II grinding stones are those of a wild barley, possibly an ancestor of the grain that fed the first farmers of the region some ten thousand years later.

Coping with Variability in Time and Space

So by late in the Pleistocene, say 20,000 years ago, modern people collectively had assembled most of the ingredients they would need to create the diversity of cuisines present today. Many technologies were yet to come; agriculture and animal husbandry, fermentation of dairy products, distilled spirits, and large-scale production of food products are some examples. However, human diets had diversified to encompass all of the major functional and nutritional categories of foodstuffs: grains and greens, large and small mammals, fish and shellfish, tubers and roots. In part, the multiplication of food types in the archaeological record is a product of improved chances of organic materials surviving as we approach the present. However, we also have less vulnerable stone and bone tools that testify to an expanded toolkit for Late Pleistocene people, in comparison to what their predecessors employed 100,000

years earlier. Like many human foragers of recent times, early modern humans hunted with sophisticated spears and bows, used snares and nets to trap game and fish, and ground hard seeds to make meal for cakes or porridge. They cooked over open fires and perhaps in baskets or animal hides heated with rocks, although ceramic technology was still in its infancy and seems not to have been applied to cooking.

Anthropologists have noted both the growing diversity of foodstuffs during the Late Pleistocene and the fact that people seem to have devised specialized techniques and tools for acquiring and processing them. Multicomponent harpoons, arrow and spear points of various sizes and shapes, fishnets and fishhooks, all stand in sharp contrast to the relative homogeneity of earlier stone tool traditions. Specialized toolkits indicate that people were beginning to tailor their methods to particular types of prey, animals and plants that were selected carefully in ways that provided adequate nutrition without wasting too much time and energy. These adjustments were never perfect and were guided by noneconomic considerations as well, but efficient hunting, fishing, and gathering probably gave the people who practiced these customs a competitive edge. The same skills that allowed humans to fine-tune their foraging to suit particular resources also allowed them to shift between strategies as conditions changed. People also came up with new strategies for coping with shortages, such as storing food and maintaining social networks that could keep the food pipeline flowing in difficult times.

BROAD SPECTRUM DIETS. Why did people pursue such a broad range of foods in the Late Pleistocene? In economic terms, consuming everything in sight that is not poisonous can be very inefficient. For example, suppose that large herds of reindeer are traversing a well-known migration route. Under these circumstances, it makes economic sense to focus one's efforts on reindeer hunting, which is a reliable source of calories that comes in a large package. In other words, investment of time and energy on a single resource that has a high rate of caloric return makes sense – at least if there are plenty of reindeer available. But suppose that reindeer become much harder to find, so that being selective means frequently passing up foods that, although readily available, have a relatively low benefit-to-cost ratio. In that case, the cost of searching for only the best resources eventually becomes so high that it outweighs the benefits of being selective. At this point, an individual can get a better overall rate of energy capture by adding a second resource, then perhaps

a third. The more expensive it becomes to find preferred animals and plants, the greater the tendency to become less choosy, thereby reducing the costs of looking for something to eat; at the same time, lower quality foods cost more per calorie to harvest and process. When the best food sources become scarce, a diverse diet makes more economic sense than a highly focused one.¹⁷

This relatively well understood relationship between food supply and food choice suggests that highly focused diets are likely when preferred resources are plentiful, whereas broad spectrum diets can be symptomatic of scarcity. Humans became very adept at tracking the changing fortunes of animal and plant populations, making informed choices about what food resources to target. We are not the only animals that exercise choice in what we eat; this is hardly surprising, given the importance of nutrition to survival and reproduction. However, we humans can switch gears with unusual alacrity, keeping up to date with the latest environmental trends and sharing that information with each other. These were useful skills to have in the unpredictable climate of the Late Pleistocene.

When resource depletion is a result of human exploitation rather than natural environmental causes, it meets the criteria for resource depression – a situation that can develop as human populations grow to higher densities. Examples of resource depression abound in the Late Pleistocene. It is indicated by reduction in the average size of mollusks at Blombos Cave from the Middle to Late Stone Age and of tortoises across the same period of time at Die Kelders Cave. This size change is a hallmark of resource depression, because people are prone to collect the largest individuals first, only resorting to smaller-sized packages when larger ones become scarce. Something similar happens in Late Pleistocene Europe with the transition from frequent use of slow-moving small game – such as tortoises – to greater reliance on faster animals such as partridge and hare. The latter cost more to capture than more sluggish creatures, but they have the added benefit of high reproductive rates, which allows them to sustain higher levels of predation without becoming depleted.

There are also instances of what appears to be extreme specialization, indicated by highly homogeneous assemblages of animal bones. Such sites occur in the Dordogne region of France, known for its cave art, where hunters took advantage of the seasonal migration of herds of reindeer. The food refuse they left behind is sometimes composed almost exclusively of reindeer bones. Whereas some have pointed to this highly

focused type of hunting as evidence of the cognitive superiority of modern humans over their archaic cousins, others argue that there is no reason to invoke special skills that we really know very little about. Reindeer specialization is just as likely to reflect an optimal choice in a very cold interval, during which reindeer were highly abundant but other animals and plants were scarce, particularly during the glacial winters.

SEASONALITY. One of the biggest problems that hunter-gatherers face is variability. There are few aspects of the natural world that are truly consistent across time and space. Our world is a living one that is constantly in flux, and like other animals, humans have to figure out – by actual reasoning or, metaphorically, through the process of natural selection – how to survive and thrive under changing conditions.

Variability itself is variable, and each sort calls for a different style of response. Many types of variability involve periodicity – repetition that is predictable, at least within a limited margin of error. Seasonal cycles are of this type, although they are subject to fluctuations in the duration and intensity of the conditions that characterize them. In temperate climates, the tilt of the earth on its axis invariably brings winter and summer in turn, separated by transitional periods of intermediate temperatures. Wet and dry seasons alternate in many tropical zones, driven by air and ocean currents and other atmospheric conditions that determine where and when it will rain and how much.

With the exception of the humid tropics, then, where conditions are pretty much the same year round, the habitats in which humans live require adjustments in diet as the seasons change, seeds and fruits ripen, animals become fatter and thinner, more or less solitary or aggressive or alert. Accordingly, groups of people tend to develop flexible but organized patterns of behavior that allow them to take advantage of abundance and avoid, or reduce the impact of, food shortages that occur seasonally.

One such response is to travel frequently, roaming the landscape in tune with natural production cycles. Archaeologically, this strategy shows up as seasonally specific sites, such as fishing camps used repeatedly only during the spring or autumn hunting camps. These are encountered much more frequently by archaeologists at Late Pleistocene sites than they are in earlier times, suggesting a structured type of mobility more efficient than the less carefully coordinated movements of archaic humans.

An alternative to traveling is storage – collecting food when it is naturally available and reserving it for later use. This strategy is first clearly in evidence during the Late Pleistocene in the archaeological record of modern humans, though many of the more elaborate technologies for preserving food come along later, with agricultural and dairy products. The earliest known storage facilities, large pits excavated below the ground surface, date to before 20,000 years ago. It is likely that belowground storage of this kind was aided by cold temperatures that retard spoilage, as long as it was not cold enough to keep the ground permanently frozen. Meat can be stored aboveground if excavation is difficult or impossible, but if not buried or concealed in some other way, food is much more vulnerable to predation or theft. Other ways to extend the shelf life of stored meat include drying and smoking, both of which were potentially available to Late Pleistocene people.¹⁸ Similar techniques can be applied to plant foods such as seeds and fruits, which may also have been stored in pits. Subterranean pits can be further enhanced as storage facilities by adding linings made of plant parts with antibacterial or insecticidal properties.

As a way to manage seasonal fluctuations in food supply, storage has some distinct advantages over mobility, particularly if the costs of travel are high. Once a group of people has invested in pits or other fixed facilities for storage, they have created ties to a particular place; in anthropological terms, they have become more sedentary. This process can snowball, with further investments (in houses, tombs, and monuments) leading to greater attachment to place, and so on. In the Late Paleolithic, we are not there yet, and high mobility is the rule rather than the exception. However, it is easy to see how a small investment in food storage can create ties to a place that grow stronger over time.

SOCIAL STORAGE. Storage is an effective way to even out periods of abundance and scarcity across the seasons. But suppose several drought years in a row leave your community without enough to eat, let alone anything to store. Unless you can move some distance away, you can only wait it out. But this dire prediction only applies if you have no neighbors or relatives to call on for help. By maintaining a social network, it is possible to get some relief through mutual aid. This kind of system works well only if the network is large enough to encompass a variety of habitats.

Social interaction can be a tricky thing to study in archaeology, because we cannot observe it directly. We rely on things, material traces

that can be situated in time and space. What they cannot tell us is how they got there and why they traveled. In the case of foodstuffs, which generally lack the distinguishing characteristics of style and form that trace the travels of pots and points, it is especially difficult to reconstruct exchange networks.

What we do know is this: Late Pleistocene people decorated things in regionally distinctive ways, and some of these objects and styles traveled considerable distances. The mechanisms that made these exchanges possible could have accommodated all kinds of goods, food included. We also know that societies both large and small in historical and modern times maintained networks of mutual assistance in times of food scarcity. The most obvious examples are current aid efforts that channel the contributions of affluent nations to famine-stricken areas. However, these networks operate on a much smaller scale, as well. When wealth differences are less extreme than they are in today's world, helping out often creates an implicit social obligation to reciprocate in the future. Such ties can be of benefit to both participants, alleviating food shortages more effectively than self-reliance alone.

It is difficult to summarize the food-related cultural changes of the Late Pleistocene in part because human communities had become established in such a wide variety of habitats that staple foods were necessarily variable from group to group. Thus, the trends we see – broad spectrum diets, precise tracking of seasonal patterns of flora and fauna, putting food in storage to fend off periodic hunger – were manifested in a very local form. The cuisines that developed regionally coincided with the growing importance of cultural transmission of traditions as a key human adaptation. Food traditions were becoming more complex than ever before, as well as more technologically sophisticated. New technologies built on ancient ones founded millions of years in the past, but other aspects of the modern human diet were more of a departure from earlier times. Food was now firmly situated in the symbolic sphere of human experience, as well as the somatic and the social. Notions of edibility, beliefs about spiritual properties of food, and the association of foodways and ethnic identity were probably part of the growing network of information connecting individuals and communities.

THE HOLOCENE. The glaciers peaked in extent around 18,000 years ago, marking the Late Glacial Maximum. From that time until the present day, the trend has been one of gradually increasing global temperatures and shrinking ice masses. There have been setbacks, most notably the

event known as the Younger Dryas, when Ice Age conditions returned to temperate zones briefly between and 11,000 and 13,500 years ago. However, the Pleistocene epoch was coming to an end, giving way to the period geologists call the Holocene, or Recent, approximately 10,000 years ago.

Gradually, the sharp fluctuations in temperature characteristic of the Pleistocene moderated, producing a global climate that was generally less variable across the years and decades. More consistent conditions allowed plant and animal populations to stabilize, and from the human perspective, this meant that the harvest and the hunt were more predictable than they had been previously. There are also indications that atmospheric conditions changed in ways that enhanced growth of plant tissues, a rise in organic productivity that rippled up the food chain from herbivores that ate the plants to the carnivores that ate other animals. Plant life flourished in places where it had long been constrained by cold or aridity, offering expanded opportunities for human foragers. Where forests spread, a more diverse fauna including smaller animals replaced the large herds of the tundra and dry grasslands.

Glacial melting had profound effects on the world's shorelines. The rising oceans swallowed islands and land bridges and carved intricate coastlines. Many plant and animal colonists, including the human variety, had established themselves on continents and large islands far from their original homes by way of land exposed as glaciers took up seawater and turned it into ice. Land routes disappeared beneath straits and seas, isolating human populations and allowing food cultures to diverge in many directions. The loss of land was complemented by the creation of resource-rich coastal and freshwater habitats that proved highly attractive to human foragers.

Many human communities flourished by taking advantage of new foraging opportunities, building on the techniques for collecting and consuming food that had served them well for many generations. But for other populations, their plant and animal prey became much more intimately connected, in a mutually dependent relationship we call domestication. That relationship was the foundation of the systems of plant and animal husbandry on which nearly all of us depend for sustenance today. How this transformation of most of the world's populations from foragers into farmers came about is the subject of the next chapter.

4

FARMERS

Why should we plant, when there are so many mongongo nuts in the world?

!Kung informant, quoted by Richard Lee in "What hunters do for a living, or how to make out on scarce resources" in *Man the Hunter*.

Curiously primitive stone tools of Ice Age provenience came to light with increasing frequency during the nineteenth century, giving rise to speculations about ancient people who lived as hunters. It seemed logical to attribute their neglect of agriculture to ignorance or some inherent deficit, because the benefits of farming seemed obvious. Instead of living hand to mouth, an agricultural people could produce surplus food and amass wealth with which to enjoy the refined pleasures of learning and the arts and to develop civilized forms of government. Savage society could only aspire to reach these heights by undergoing progressive evolution to a more advanced state, one prepared to invent or accept the agricultural way of life.

Modern ethnography cast doubt on the inevitability of agriculture and animal husbandry, especially when the prevailing image of hunter-gatherer life flipped from hand-to-mouth desperation under harsh conditions to a more realistic, if sometimes romanticized, vision of limited labor and abundant leisure time free from drudgery. With this shift in perspective, the adoption of agriculture and animal husbandry demanded explanation. Instead of seeming mysterious, the failure to make the transition to agriculture looked more like an understandable reluctance to leave behind the relatively stress-free, peaceful, and nutritionally sound lifestyle of the hunter-gatherer band. New questions emerged about why this apparent paradise was ever lost, to be replaced

by the dusk-to-dawn work life of the farming household that became the norm for most of the Earth's populations.

We now know that before 12,000 BP (10,000 BC),¹ human groups everywhere sustained themselves exclusively through hunting, gathering, and fishing. To be sure, there were times of deprivation when nut harvests failed or harsh winters pushed animal populations to the brink of survival. Even times of relative abundance involved work. Still, if we look at life from the perspective of the !Kung informant cited at the head of this chapter, the swift transition to the agricultural way of life beginning in the early Holocene does seem to call out for explanation. After all, raising crops and herding animals requires work beyond the making and maintaining of tools and weapons, capturing and harvesting, transporting and preparing. Fences must be built, fields prepared, seeds planted, and seedlings tended and protected. Some environments require landscape modifications such as terracing hillsides to limit erosion or irrigation to feed thirsty crops. Why commit to this kind of workload when wild wheat and barley can be harvested for free, small animals caught in traps, and fish hauled in with nets? Or does the farmer willingly invest effort in return for greater yields and a measure of food security?

THE QUESTIONS

The practice of food production is based ultimately on a set of intimate ecological relationships between people and the plants and animals that provide them with food. We can see these relationships everywhere, if our eyes are open to them, and thereby understand how ubiquitous they are. Their existence is no mystery if we pay attention to the way natural selection preserves some forms and allows others to perish. When people change the environment, for whatever reason, they change the calculus of selection affecting the species around them. The subtle pressures and opportunities created in this way jump-start the process of domestication, leading plants and animals chosen as food down a different evolutionary path than they would have followed in the wild. Seen from this perspective, agriculture is one of many possible types of feeding adaptations available to animals.

But there are features of the agriculture practiced by *Homo sapiens* that makes it different from parallel examples in other organisms, such as fungus-growing ants. Human agriculture is molded by our ability to innovate, allowing us to adapt farming techniques to all but the most

extreme habitats with the assistance of technology. Our ancestors used their cognitive skills to try out different combinations of hunting, gathering, farming, and herding in response to environmental conditions that were undergoing significant change at the start of the Holocene. Population dynamics were also in flux in some parts of the Earth, where the density of human settlement reached levels at which competition for food and other resources began to erode economic efficiency and create shortages. Human decisions made in response to these environmental factors are the key to understanding why agriculture was quickly incorporated into the cultural repertoire of so many of the world's populations.

The other distinctively human factor that makes our brand of agriculture unique is its cultural dimension. The incorporation of increasing quantities of domesticates, especially grains and other starchy foods, into human diets stimulated an array of techniques to make meals more digestible and palatable. These innovations became encoded culturally in the form of regional cuisines, bodies of knowledge that prescribe the proper ways to prepare, combine, and consume foods. Cuisines traveled along with the agricultural technology that accompanied early farmers on their migrations, leaving distinctive archaeological traces.

THE NATURAL HISTORY OF AGRICULTURE

Attine ants are obligate farmers.² For the last fifty million years, they have been exploring the agricultural niche by gathering leaves to create fungal gardens. Within this group, the leaf cutter ants have developed the additional specialization of processing leaves into a substrate that can be assimilated easily by the fungus. They also have castes that perform different agricultural tasks, such as removing debris and secreting antibacterial chemicals from specialized glands. Some of the fungal strains have become domesticated to the point of being completely dependent on their ant cultivators for survival. They even develop special structures that concentrate nutrients in easy-to-collect packages that facilitate harvesting. By any accepted definition of the word, attine ants have agriculture: they plant on a regular basis, and cultivate and harvest a crop on which they depend for nutrients. Some strains of fungus are even domesticated; they have changed from the wild state in ways that benefit their ant stewards, on which they now depend for survival.

The purpose of bringing up fungus-growing ants at this juncture is to make the point that *agriculture is based on a kind of ecological interaction that is widespread in nature and understandable as an outcome of evolutionary*

processes. Ant agriculture and human agriculture both emerged by way of coevolution in which the species involved benefit from a persistent, structured feeding relationship known as mutualism. This is true even though the mechanisms that produce and perpetuate agricultural behaviors are for the most part quite different (people learn to farm and teach their offspring, whereas ants minimize learning in favor of largely automatic responses to environmental stimuli). We should, thus, be able to gain some insight into human agriculture by focusing on how these coevolutionary relationships develop, why they work, and what kinds of changes they produce in the participants.

Domestication as Natural Selection

The process of coevolution is driven by natural selection, the mechanism that Charles Darwin proposed as the chief cause of the diversity of life forms. His theory was simple, but had considerable explanatory power. Within any species, individuals vary, however slightly, and some of the traits that vary are heritable. Those variants that have a competitive edge in a particular habitat tend to leave relatively more descendants, thus passing on their beneficial traits. This process – natural selection – weeds out some individuals and traits while allowing others to persist. Over time, organisms become more closely adapted to the environments in which they live, sometimes diverging enough from ancestral forms to become a new species.

Darwin realized that it would be difficult for many of his readers to accept that a mechanical process such as natural selection could fit organisms to their conditions of life so precisely. To make this startling conclusion more palatable, he began his explanation of natural selection in the *Origin* with a clever rhetorical device that compared it to the selective breeding practiced by farmers and hobbyists such as pigeon fanciers. The same process operates in nature, with the sole difference being the agent that determines which individuals survive and reproduce. Whereas the plant or animal breeder plays this role in the greenhouse or experimental field, in the wild it is the impersonal force of the conditions of existence that “chooses” the parents of the next generation. This mechanical process, which culls the less competent individuals and preserves those with superior survival skills, Darwin called natural selection.³

We can take the analogy a bit further to explore the territory between the Victorian pigeon-fancier striving to achieve a desired feather color

or bill shape and the effects of selection completely outside of human influence. It is in this in-between space that agriculture has its origins, for humans have a knack for altering the habitats in which they live in ways that guide natural selection along certain paths, even without intending to do anything of the kind. This phenomenon is ubiquitous. Every time you mow the lawn, you are favoring weeds that can mature and produce seeds below the level of the mower's blades; taller individuals get lopped off, never to reproduce. Removal of trees opens up the soil to sunlight, favoring fast-growing weeds that colonize such open spaces and produce abundant seeds and fruits. Even fire, far from being universally destructive, can encourage new vegetative growth and prolific yields of fruit in some species of trees, while damaging others and ultimately changing the composition of entire forests. It is easy to imagine how many of the activities engaged in by prehistoric people might have jump-started the engine of agriculture, leading to more intentional types of management that we usually associate with the farming life. Along this continuum from unintentional habitat modification to organized agriculture lie many possible ways of life, not all of which are easily categorized as either foraging or farming. They involve varying combinations of technologies and activities: selective removal of competitors, supplemental watering and feeding, transplanting, protecting, even pollinating and grafting.⁴

Initially humans may act without a goal in mind, but they learn quickly how to manipulate the process to their own advantage through selective breeding. In the case of plants, they may sow seed casually without replanting, or they may take the important step of replanting some of what they have harvested, thereby selecting for traits that may be useless in the wild (such as the inability to disperse seeds). Similarly, animals with aggressive temperaments that fail to adjust to close contact with humans are likely to be removed from the domesticate gene pool. In this way, the characteristics of the domesticated population come to diverge from the wild state as they become more closely adapted to the agricultural environment.⁵

It is to these adaptations that archaeologists must look for clues to the transition to agriculture in the prehistoric past. Archaeobotanists and zooarchaeologists, trained respectively in the identification of plant remains and animal remains from archaeological sites, reason from the distinctive forms of domesticated plants and animals to the past practices that produced them.

The Archaeology of Domestication

Fortunately, the distinctive shapes and sizes of domesticated plants are frequently preserved in the archaeological record. Metric analyses can be used to place archaeological seeds and fruits along the continuum from wild to domesticated, based on what we know about modern-day varieties and how they evolve under human management.⁶ From these observations, we can make some predictions about what direction selection will take when humans are exerting a strong influence on it. For example, the part of a plant that is used tends to increase in size. Fleshy fruits provide some of the most obvious examples: crabapple versus Granny Smith, for instance, or the tiny wild strawberry and its monstrous (and often flavorless) cultivated counterpart. Whereas such cultivars are products of many generations of careful selective breeding, some of the first steps toward domestication are taken without such conscious effort.

The simple action of harvesting a stand of wild grasses, such as wheat, and then sowing seed from that same harvest *automatically* favors plants that germinate early, grow quickly, and mature at the same time, because these are the ones that fall to the sickle and produce the next generation. The method of harvesting is of crucial importance here, for a technique that relies on the tendency of ripe seeds to fall to the ground – such as collection in baskets by shaking or beating on the seed heads – will have precisely the opposite effect on the direction of selection. Subsequent generations from this sowed seed will not lose the ability to disperse naturally, avoiding the fate of most domesticated cereals, which surrender reproductive independence for the security of annual sowing.⁷

In animals, the first steps toward husbandry probably entail behavioral changes that are largely invisible to the archaeologist, although some of these are reflected in such traits as smaller brains and reduction of horns (which help males compete for females in the wild). Often a more telling signal of herd management comes from the age and sex composition of reconstructed populations. Such is the case for goats in the Near East. Melinda Zeder compared toe and leg bones of both modern and archaeological goats from modern-day Iran and Iraq.⁸ She found that although there was no overall reduction in body size as a result of domestication – a criterion that had been proposed in previous work – there were significant differences between male and female

goats, a phenomenon known as sexual dimorphism. Zeder also discovered that the age at death of individuals as indicated by the degree of fusion in the actively growing ends of long bones such as the femur (thigh bone) revealed that female and male animals had different life expectancies under human management than they did in the wild. Most male goats were killed while still young, whereas females were allowed to grow to a more mature age before being slaughtered. This pattern is much like the practice of contemporary herders on the Near East, who keep adult females to reproduce (and yield dairy products), killing superfluous young males for consumption. The assemblage of bones that accumulates under these conditions is very different from that of hunting, which tends to target mature males to maximize the amount of meat captured.

From Morphology to Molecules

Goat toes and giant seeds are all very well as proxies for assessing domestication, but what of the underlying genetic variation? Inheritance drives the process that pushes organisms along the continuum from wild to domesticated. Whereas natural selection – and artificial selection, until very recently – can only act on features of the organism that respond to the environment around them (the phenotype), it is the relatively insulated genetic code, or genotype, that carries information between generations. In the stark logic of natural selection, survival is irrelevant if it does not translate into offspring.

The techniques needed to study this genetic variation directly, rather than through the proxy of phenotypic change, are relatively recent developments. It is only in the last decade that automated sequencing has made it possible to review large segments of complex genomes, in some cases permitting researchers to compile complete libraries of an organism's genetic code. A much more challenging task is to identify genes responsible for specific traits; however, progress is being made here as well. For instance, new techniques have enhanced knowledge of maize, which has become a major world crop since it was first cultivated in central Mexico around 3000 BC. This plant has long been studied by geneticists, both for practical reasons such as higher yields and as a model organism for understanding broad principles of genetics. This research history has been a boon for archaeologists, who want to know when people began selecting for particular traits, such as the starch and protein content of kernels.

Although living maize plants reveal the genetic control of such traits, it is ancient cobs from archaeological sites that provide the final piece to the puzzle regarding which qualities ancient people sought to preserve and perpetuate. What makes this inference possible is the fact that some of the preserved cobs still contain DNA in sufficient quantities to amplify for study. Comparison of the ancient and modern sequences has revealed that the kind of starch favored for making tortillas was present in Mexico as early as 2400 BC, whereas cultivars from New Mexico dating to AD 1000 and later were more likely to have hard kernels, similar to today's flint varieties.⁹ Here is a clear record of prehistoric management of a food crop to satisfy culinary requirements.

A Two-Way Street: Human Biological Adaptations

Whereas domesticated plants and animals are often distinguished by morphological traits that differentiate them clearly from their wild relatives, the same is not true of the farmers. They are recognized instead by their behavior and the cultural traditions that accumulate to guide their interactions with domesticates. However, the increased consumption of agricultural foods has left its mark in the distribution of certain genetically linked traits among human populations. The best known example is probably that of the continued production of the enzyme lactase into adulthood. Lactase breaks down lactose, a sugar found in raw milk products, so that it can be digested efficiently by nursing infants. In some 70 percent of the world's populations today, adults lack this ability and suffer bloating and diarrhea when they consume raw milk. This happens because in the absence of lactase, bacteria in the human gut are free to consume lactose, producing gas as a byproduct. But in the remaining 30 percent of populations, a mutation has spread that keeps lactase production going throughout the lifespan, allowing adults as well as children to digest milk. This condition is associated historically with the practice of dairying, which lends a selective advantage to individuals who can make full use of milk products; otherwise, producing lactase for a lifetime is just a waste of energy. An alternative behavioral adaptation is fermentation of milk products, which reduces lactose content, thereby diminishing the relative advantage of the adult lactase mutation.¹⁰

There is a similar correlation between the starch content of human diets and the number of copies of a gene that controls production of salivary amylase, which breaks down starch. The more copies that are

present, the more amylase is produced, a useful trait for people who rely on carbohydrate-rich foods. The mutations that produce extra copies, therefore, tend to spread in agricultural populations, in which grains and USOs are usually staple foods. Without high starch consumption, extra amylase cannot pay for its own production by extracting more energy from food.¹¹

So people have been changed by agriculture, just as their dependent domesticates have been, although the changes are hidden in the genes and the body chemicals whose synthesis they guide. Although profound, human biological adaptations to agriculture are unintended and controlled by natural, not artificial, selection. Perhaps we are domesticated, too.

THE HUMAN FACTOR: DECISIONS AND REVISIONS

Humans are caught up in the same web of ecological interactions as other organisms and are subject to natural selection. This view makes sense of the way that human populations have coevolved with their animal and plant domesticates; it gets us part of the way to explaining the origins of agriculture. But to understand the directional thrust of this new way of acquiring food – why it snowballed as a central economic strategy and why it spread across continents and between populations with such alacrity – it is necessary to shift perspectives and turn to the behavioral flexibility and cumulative social learning that make humans unique. Innovation and experimentation with food resources, long part of the human behavioral repertoire, crossed over into new territory during the Holocene. The large, frequent, and unpredictable fluctuations in yields of the glacial era gave way to a more stable pattern, giving people time to acquire and accumulate the skills needed to make animal and plant husbandry work. These climatic changes removed constraints that kept human communities from extracting increasing amounts of food energy from the land, allowing agriculturalists to spread at the expense of their foraging neighbors.

Intensification and Its Limits

Intensification is the process of increasing production by investing additional labor. Usually this entails some loss of efficiency, as production does not pay off in direct proportion to the increase in effort (in other words, the *rate* of return diminishes over time, even as the absolute

quantity of captured energy increases).¹² Subsistence intensification takes different forms in foraging as compared to farming communities. In agriculture, it translates into higher yields of food per unit land under pasture or cultivation at the cost of greater investment in activities such as tilling, weeding, fertilizing, and sowing. Agriculture has the potential to achieve yields per unit of land that are beyond the reach of even the most productive hunter-gatherer economies. However, hunter-gatherers can also intensify subsistence by inventing or adopting new technologies that make more food available. Intensification might be accomplished, for example, by adding resources that are abundant but costly to capture or process (such as small seeds or toxin-containing roots). Intensification might, therefore, appear in the archaeological record as an increase in the number of plant and animal species represented in refuse deposits, along with specialized tools such as grinding stones and snares (this pattern should sound familiar from the discussion of broad spectrum foraging in Chapter 3).

An important question here is why people bother to intensify, which after all involves time-consuming and often tedious labor. One possibility is resource depression, discussed in the previous chapter; over-exploitation of preferred resources can cause scarcity and the need to resort to less-valued sources of calories. In this context, intensification is a response to shortage – it increases production beyond current limits, but with some loss of efficiency. Any decline in resource abundance, whether or not people are responsible, inspires consumers to extract more out of less, by inventing better tools and techniques or simply putting in more time. Intensification may also be driven by a kind of “cultural ratchet” effect, in which cumulative improvements in subsistence technology drive population growth, which, in turn, demands further intensification. Human populations caught up in this cycle tend to have a competitive edge over those not so equipped.

The cultural ratchet is one element of a cogent theory developed by Peter Richerson, Robert Boyd, and Robert Bettinger to explain the origins of food production.¹³ What these scholars argue is that, driven by improvements in technology, intensification was underway in many human communities during the Late Pleistocene; however, its continuing trajectory was constrained by the great magnitude and unpredictability of climatic fluctuations. Any attempts to improve production by raising crops would have been interrupted by catastrophic harvest failures, and the accumulation of accurate cultural knowledge about agriculture was probably stymied by constant environmental change.

Then, during the Holocene, sharp variations in temperature range and length of growing season evened out. Many regions that had been too dry or too cold to support abundant plant life became more benign during the Holocene, and increased CO₂ levels promoted the growth of vegetation globally. These conditions made it possible for human communities to reach a new level of intensification – agriculture.

The Near East gives us an opportunity to see how this sequence of events might have taken place on a compressed time scale. We saw in Chapter 3 how relatively low-value plant and animal foods appear at some sites during the Late Pleistocene, along with the tools needed to exploit them effectively. These signs of intensification are highly visible in sites of the Levant region belonging to the Natufian culture (12,000 to 9600 BC). Natufian settlements were densely occupied and relatively stable over time, with mud brick houses and storage pits. Natufians were settled hunter-gatherers with an economy that relied on a variety of plant and animal resources, including wild grasses and tree fruits, gazelles, goats, and sheep. There is strong evidence that the Natufians cultivated wild cereal grasses such as wheat and barley, although these grains are virtually identical in form to wild types that still grow in the Near East today. This step was made possible by the climatic amelioration underway at the start of the Holocene.

A brief return to late glacial climatic conditions called the Younger Dryas (10,800 to 9600 BC) disrupted the Natufians' venture into food production; they returned to a more mobile foraging way of life. However, the interruption of the agricultural trend was only temporary, and when the climate ameliorated once again, farming villages sprang up across the Near East, and domesticated forms of goats, sheep, barley, wheat, and other species become a common feature of the archaeological record.

Some of these Near Eastern farmers and their domesticates colonized southeastern Europe. The first of these colonists spawned daughter communities, a process that continued until most of the European continent was occupied by farmers or their descendants. European populations of today show the influence of those first Near Eastern immigrants, in the form of distinctive genetic signatures (see Chapter 7 for a more detailed exploration of this topic). Technological information and domesticates moved as well as the people themselves; intermarriage and friendly trade relations assured that indigenous hunter-gatherers had the option of adopting agriculture. Whatever the mechanism by which agriculture spread, it did so at the expense of the foraging way

of life. Ultimately, farmers have bigger families and their populations grow, absorbing or displacing competitors for land and resources.

The Natufian case nicely illustrates the feedback between intensification, technology, and population growth that can lead to the expansion of agriculture into new geographical territory. In the Near East, this process was rapid under postglacial climatic conditions. In other regions, such as eastern North America, the cultural ratchet moved at a more leisurely pace. Human populations were spread out over a larger land-mass and seemed to do quite well hunting deer, fishing, and collecting hickory nuts to keep themselves fed, at least until around 3000 BC. Here, the transition to agriculture was more gradual than it was in the Near East and seems to have been triggered not by the drive to maximize efficiency or total yields, but by the usefulness of cultivated plants as seasonal fallback foods.

Food Production and Storage

One day in 1935, William S. Webb of the University of Kentucky shipped a package to the director of the Ethnobotany Laboratory at the University of Michigan in Ann Arbor. Webb had been excavating archaeological sites in eastern Kentucky rockshelters in which he encountered large quantities of organic remains left behind by their prehistoric inhabitants (Figures 4.1 and 4.2). Not knowing quite what to make of these assemblages of seeds, nutshells, squash rinds, and grass stalks and fibers, he sought expert advice from laboratory Director Melvin Gilmore and his assistant, Volney Jones. On examining this material, Jones immediately wrote back to tell William D. Funkhouser, head of the Department of Zoology at the University of Kentucky, to please retain any other specimens of ancient plant material, which were of great scientific interest. On receiving Jones' report, Webb admitted regretfully that he had been in the habit of discarding the thick accumulations of "vegetal material" which he had initially assumed to be without value.¹⁴

With this correspondence began the discovery by science of what was to become known as the Eastern Agricultural Complex (EAC). Some thirty years after Jones' publication, "The Vegetal Remains of Newt Kash Hollow Shelter,"¹⁵ large-scale excavations in Illinois and Tennessee began routinely using the flotation method to recover delicate plant remains from archaeological sites. This work, along with detailed studies of how sunflower and other crop plants changed under domestication, established that eastern North America was home to a suite of native crops and an entirely original type of agriculture that preceded



FIGURE 4.1. Maygrass (*Phalaris caroliniana*) from the Newt Kash rockshelter, Kentucky. This plant was cultivated and stored by prehistoric farmers of the eastern United States, although it does not exhibit the increase in grain size seen in many domesticated grasses. This material is at least three thousand years old. Photograph by the author.

the better-known and much later maize-based economies encountered by the first European explorers.¹⁶ These earlier forager–farmers of the American midcontinent grew seed crops that evolved from weeds of disturbed ground, plants that thrived in the open habitats around human settlements, in river bottoms, and on unstable slopes. Their practice of cultivating low-cost crops as insurance against seasonal food scarcity is sometimes referred to as “low-level food production”¹⁷ to differentiate it from the fully committed, intensive cereal-and-animal-husbandry economies of the Near East and elsewhere.

The eastern North American seed crop complex seems to have had a rather different set of factors involved in its origin than those that drove the emergence of Eurasian cereal agriculture. For one thing, the timing of the EAC postdates the start of the Holocene climatic era by 5,000 years or so, well into the stable post-Pleistocene regime amenable to agriculture. Intensification in the broad sense was just beginning in the resource-rich habitats of the East, such as the woods and wetlands of the large midcontinental river valleys, at the time when evidence first

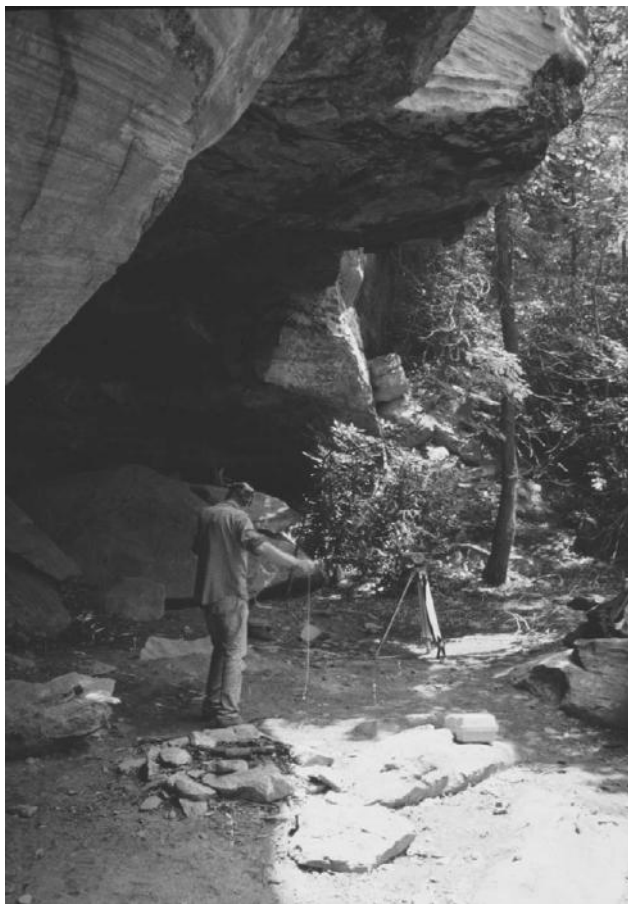


FIGURE 4.2. Archaeologist at work in a rockshelter in eastern Kentucky. These sandstone overhangs, with their dry, nitrate-rich sediments, are ideal environments for preservation of organic material. Much of the evidence of early farming in eastern North America comes from rockshelters and other protected sites such as caves. Photograph by the author.

comes to light of domesticated versions of sun-loving weedy plants such as sunflower and goosefoot. The communities that first pursued the weed crop strategy probably varied in size, but were certainly much smaller than the densely populated Natufian and Neolithic villages of the Near East. If population growth was fueling further intensification, it was doing so at much slower rate, one not easy to detect in the archaeological record.

So how did cultivation of plants get started in the East? Even before the first seed was planted, a number of elements converged to create an environment ideally suited for the development of human-plant interdependence. The first of these was the abundance of disturbed habitats that punctuated the blanket of hardwood forest covering the region in precolonial times. Many of these habitats were created and maintained, whether willingly or without intent, by humans. Pre-agricultural foragers cleared patches of forest for settlements and burned over woods to encourage new growth that might attract deer and other game. Although the scale of such disturbances was small compared to later land clearing efforts, they nonetheless created patches of disturbed soil that received a full dose of sunlight: a perfect environment for native weedy plants to become established. These plants thrive under ongoing disturbance that keeps seedlings from maturing into shade-producing trees, under whose canopy sun loving species cannot flourish. Plants such as goosefoot (*Chenopodium berlandieri*), marshelder (*Iva annua*), and a native thin-shelled gourd (*Cucurbita pepo*), already adapted to the unstable soils of river bottoms, readily made the transition to analogous habitats created by human activity.¹⁸ With their broad tolerance of soils, temperature, and moisture conditions, these unassuming weeds were able to thrive in human company even outside of their original riverine homes. Other plants of disturbed ground also joined the suite of EAC crops, for example the sunflower (*Helianthus annuus*).

People began to play a more active role in dispersing these plants when they crossed the critical threshold of planting, harvesting, and replanting that nudges natural selection to preserve traits beneficial to life under cultivation.¹⁹ The first signs of morphological change that signaled domestication and incipient agriculture appear by 2300 BC in the Illinois River valley. Marshelder seeds became much larger than they had been in the wild; goosefoot seeds developed a thinner coat that helped them to germinate rapidly when planted. The weedy sunflower began to take on the familiar form we know today, with a single central cluster of large oil-rich kernels encased in their brittle shells.

Why people made the transition to cultivating seed crops is a question that has been answered only in part; however, the function of oily and starchy grains as insurance against winter food shortages played an important role. This interpretation springs from the confluence of several different lines of evidence. One of these comes from a rare, but valuable, data source: the remains of ancient human feces. Many of these desiccated paleofeces have been preserved for thousands of years in

caves and rockshelters protected from the elements, in sediments so dry that the microorganisms that decompose organic remains are inhibited or excluded. As a result, their contents are preserved, including food remains tough enough to survive the digestion process. Among these remains are seed coats from goosefoot, marshelder, native squash, and sunflower, all bearing the distinctive marks of domestication. Not only do these seed remains demonstrate unequivocally that people ate them; they also provide a tool for determining what time of year they were consumed. This is possible because each stool contains a variety of items that were ingested together or near the same time, including pollen and seeds. Combinations such as high concentrations of oak and pine pollen (which are dispersed by wind during the spring in temperate North America) with crop seeds signal a meal eaten too early in the year to coincide with the annual harvest. Thus, there can be no doubt that seed crops were stored for use in winter and spring, when many other foods are scarce.²⁰

Seeds were stored in belowground pits or aboveground in woven bags or baskets. Many of these textiles have been preserved, in some cases with their contents still *in situ*. Perhaps this is all that was required to keep food safe – a secluded spot free of damaging organisms. However, pits dug into the dry sediments had the advantage of keeping stored seeds hidden, both from rodents and other people who might stumble across the cache. Once used for storing hickory nuts and other tree seeds, storage pits became increasingly common at sites with evidence of seed crop agriculture. Although these depressions usually fill with refuse unrelated to their original storage function, in a few cases they retain a lining of bark or grass along with some of the seeds they once protected.

Along with the direct evidence that seed crops were stored and eaten out of season, the geographical distribution of communities that relied on this strategy suggests a connection with the length and severity of winter months.²¹ The greatest quantities of seeds of cultivated plants – and, by implication, the intensity of food production – are found in the American Midwest, where several great river valleys converge. It is here that we find the sites most widely known for their rich seed assemblages. In contrast, the Coastal Plain of the deep South has preserved virtually no evidence of small seed cultivation. The zone geographically intermediate between these two reflects a partial commitment to farming before maize became a staple crop (after about AD 1000; Figure 4.3). The boundaries between the three zones roughly follow

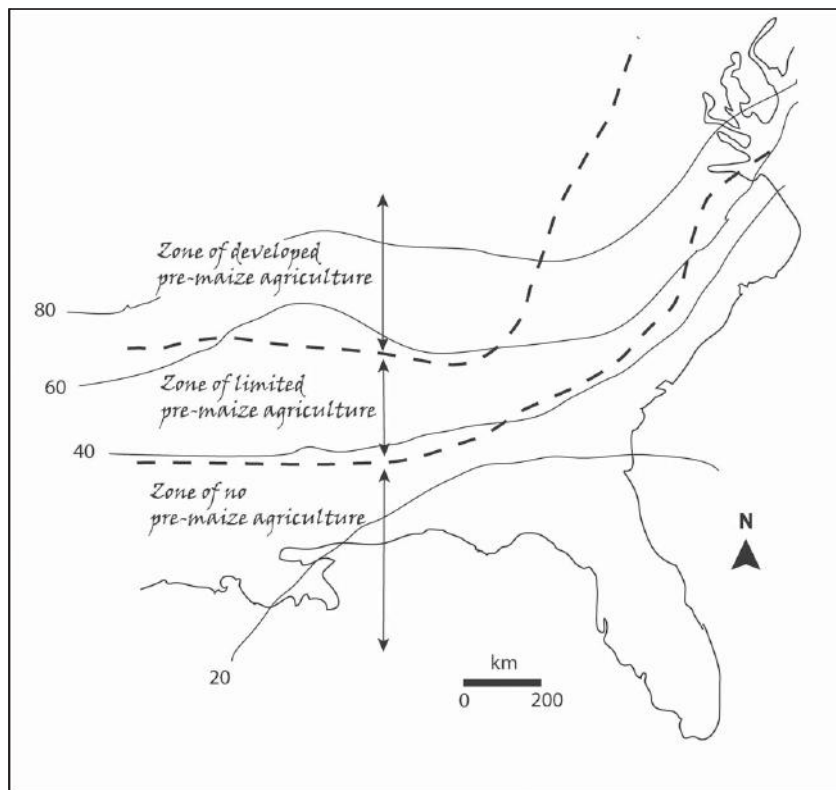


FIGURE 4.3. Map showing the relationship between the degree of dependence on agriculture (as indicated by archaeological plant remains; dashed lines) and the length of the growing season (estimated from the average number of days annually on which temperatures fall below 32° F; solid lines). The economic importance of cultivated plants tends to be greater where the growing season is relatively short.

the lines, or isotherms, that meteorologists draw to connect points with the same average number of days with temperatures that drop below 32° F. This correspondence between cultivation and cold seems to be weaker in the northeastern United States, where we would expect more evidence of agriculture than there actually is. This divergence may be a result of missing data, but for the most part the pattern connecting frost-free days and reliance on food production seems to reflect what people were actually doing during the two millennia between 1000 BC and AD 1000.

Another reason to favor storage as a key motivation for seed cultivation is the economic inefficiency of collecting and eating small seeds

during warm weather, when more profitable alternatives such as nuts, fruits, and game are plentiful. Small seeds reside near the bottom of any ranked list of resources – they may be cheap to harvest, but tend to be very costly to process. Usually these foods are ignored, unless the alternatives just become too expensive to pursue, as when resource depression or a lengthy period of adverse conditions affects animal and plant populations. If these conditions do not intervene, people tend to ignore small seeds unless the alternatives are very limited, as they are in the cold season of temperate zones. During those periods, with food supplies dwindling and other activities curtailed, time might be well spent threshing and pounding the nutritious seeds that had been collected at harvest time.²²

The case of eastern North America contrasts in many ways with the Near East and many of the other “hearth” areas of agriculture. Ecologically, there are similarities – in both cases, harvesting and processing of small seeds made a gradual transition to more active management of domesticated plants. Disturbance of natural vegetation and food storage played some role in both regions. However, the search for causes leads in very different directions – toward a fairly rapid upward spiral of growing populations with limited natural food resources in the case of the Near East and to a more gradual and opportunistic process in eastern North America. In North America, people were not on the verge of making the transition from forager to farmer by the time climate began to stabilize enough to permit agricultural systems to persist. Initially at least, the relatively costly small seed crops played a dietary role that was limited, primarily or exclusively, to that of a backup resource to tide people over to the next growing season. Weed crops did come to achieve a greater degree of economic importance over time, perhaps indicating a gradual intensification as yields improved and human populations grew. Eventually these modest native crops were eclipsed by maize, an immigrant from the drylands of Mesoamerica. Thereafter, most of these members of the EAC have quietly retreated to their former weedy niche, their past as foundational crops largely forgotten except by prehistorians.

BETTER LIVING THROUGH CHEMISTRY

There is a natural connection between intensification and technological innovation. The additional effort needed to step up the production of food provides a powerful incentive for people to find ways to make

their activities more efficient. Here the human facility for invention comes into play. Not only can we try out new ways of using our bodies to manipulate the environment, which is something that many animals can do; we can further expand the range of possible novel behaviors by making and using specialized tools. Thus, it is not surprising that agricultural life spawned some new techniques for processing food efficiently and making it more palatable.

Pots, Griddles, and Ovens

A diet rich in cereals and other grains cries out for tools and techniques that can make these bland and often nutrient-poor foods palatable and nutritious. The process of grinding that is necessary to release nutrients for absorption by the body has been around at least since the Upper Paleolithic period, when occupants of Ohalo II used it to prepare wild grass seeds (see Chapter 3). What they did with the resulting flour or “grits” is not certain; however, neither these people nor their immediate Neolithic descendants had pottery or ovens. How did they transform hard grass seeds, bristling with sharp protective structures, into a palatable meal?

At Ohalo II, flat stones that appear to have been heated may have been used for cooking. It is a fairly simple matter to make a flatbread by combining flour with water and spreading the dough on a hot surface to grill. This is a common technique for making various types of flatbread found worldwide, from tortillas to papadum. Even nonagricultural peoples, such as indigenous groups of the Australian interior desert, take advantage of the griddle method to cook “dampers,” mixtures of ground wild grass seeds and water.²³

There is also the option of cooking the grain product in water to form a gruel. However, this method does require one specialized type of equipment – a watertight container. Baskets or animal hides can be made watertight, but they cannot sustain direct heat; instead, the water in these vessels must be heated indirectly by placing hot stones or other nonsoluble objects in it. This indirect heating method has some limitations – the temperatures it can produce are fairly low, more like simmering than boiling, and it can only be sustained by continually adding more heating elements (such as hot rocks). To efficiently get a container of liquid to boil, which is what is needed to break down complex carbohydrate molecules, you need to heat it directly. This property is partly responsible for the origin and widespread adoption of ceramic

vessels for cooking. Ceramic pots are watertight, and depending on particulars of vessel form, clay and temper, can sustain direct heating without breakage. If the invention of pottery did not make porridge possible, it made the process of wet-heat cooking more reliable, more consistent, and perhaps more efficient.²⁴

In fact, the invention of pots that could withstand direct heat, coupled with production of seed crops, played a major role in boosting population growth among early farmers of eastern North America. Seed crop farming was well established in west central Illinois by the time the first pottery appeared about 600 BC. The earliest pots had thick walls and the clay from which they were made had been tempered with coarse chunks of rock. Tempering agents help to keep pots from cracking during firing as the clay dries and shrinks. After 200 BC, pots were showing a trend to thinner walls and finer temper, both of which help pots withstand thermal stress, making them more suitable for direct heat cooking. People also seem to have experimented with varying wall thickness and wall curvature in an attempt to retain the thermal conductivity and stress resistance of thin walls without sacrificing the mechanical strength of thick-walled pots. These improvements in cooking technology track the trend to increased presence of seed crops in archaeological deposits. Some archaeologists argue, not without justification, that the availability of starchy gruels to wean infants at earlier ages was behind the well-documented growth in human populations in Illinois during this same period of time. Weaning inhibits lactation, and as milk production stops, pregnancy becomes more likely; thus, gruel translated indirectly into population growth.²⁵

Given a choice, most of us would probably prefer a warm loaf of freshly baked bread to a steaming bowl of gruel. Whether Neolithic farmers felt the same way is impossible to know; however, pottery does appear earlier in the Near East than definite evidence of bread baking. The wheat loaf of today is made with wheat high in gluten, leavened with the help of microorganisms such as yeast or bacteria, and baked in an enclosed oven. These three components of bread making do not appear simultaneously in the archaeological record; however, all were in place at least by about 4000 BC, and probably earlier. Ovens date to as early as 7000 BC in Iraq and Turkey, but they were not necessarily used to bake bread; specialized bread ovens do not predate 3100 BC. The use of yeast to create leavened bread was practiced by the ancient Egyptians by about 4000 BC, but may well have been much earlier than that. Naturally occurring yeast and bacteria can also serve as leavening

agents, creating carbon dioxide as a metabolic byproduct, which in turn creates air spaces in the dough that give bread its fluffy quality. The key to this process is gluten, an elastic compound that is formed by kneading dough that contains the storage protein glutenin. Wheat, barley, oats, and rye all contain some glutenin, but wheat has the highest concentrations. Bread wheat, a cultivar with unusually high glutenin content, was probably developed between 7000 and 5000 BC.²⁶

Functional Foods: Succotash and Hominy

Folk chemistry inspired by agricultural diets did not stop with cooking, however. Other kinds of chemical reactions lie behind some of the most innovative methods for improving the nutritional quality of a calorie-rich, but nutrient-deficient, diet. One example is nixtamalization, the practice of soaking maize kernels and cooking them in lime or wood ash solution. Besides softening the outer skin of the kernel (the pericarp), this process improves the availability of the B vitamin niacin to the human body, deficiency of which can cause pellagra, a debilitating disease. Where maize is a staple food, alkali treatment is essential to keep people healthy. Nixtamalization is practiced widely in Mesoamerica, where it has been used in making tortillas for at least 3,500 years. In the southern United States, where maize has long been a staple in the diets of rural people, the treatment of maize kernels with lye yields hominy. Swollen and mealy, hominy is now found mostly as a canned product on grocery shelves, largely unfamiliar in North America outside of the South.²⁷

Maize has another nutritional downside in its deficiency in two essential amino acids, lysine and tryptophan. Fortunately, this shortage can be remedied by consuming legumes such as beans in the same meal, or even in the same dish – as a bean taco, for example, or succotash.²⁸

Fermented Dairy Products

Animal husbandry, especially of cattle, sheep, and goats, is a valuable source of calories, calcium, and vitamin D for adults as well as children, at least in populations that have high rates of lactose tolerance. However, there is another way, besides the relatively slow process of natural selection, to keep milk in the diet. Difficulty digesting lactose can be circumvented by fermenting milk to make cheese. Cheese enters the human body essentially predigested by the bacteria that curdle or ripen

it. The process of fermentation gets going readily without human help – just leave a carton of milk out on the counter for a few days. Although curdled milk makes for a lousy cup of *café au lait*, more sophisticated manipulations have resulted in the great variety of cheeses we know today, from the relatively bland ricottas and cottage cheeses to the more aromatic Stiltons and Bries, which are aged to incorporate the strong flavor of bacteria and its byproducts.

The geographical distribution of adult lactose tolerance illustrates an important fact about the relative virtues of raw milk and cheese in different environments. Raw milk is especially valuable as a source of vitamin D in environments that have a shortage of sunlight, either because of cloud cover or long winters with short periods of daylight. Ultraviolet light is needed to help the body synthesize vitamin D, which otherwise has to be obtained from an external source such as raw milk. Fermented products do not provide the same benefit. Where this sort of conflict exists between getting enough vitamin D and avoiding severe indigestion, such as the northern latitudes of Europe, natural selection has favored the lactase gene rather than (or in addition to) cheese making.

There is good evidence that the first Europeans to adopt Near Eastern animal domesticates were not pre-adapted to milk drinking. Some, at least, of these early Neolithic populations lacked the genetic variant that confers lactose tolerance in adulthood, based on analysis of ancient DNA from a small sample of human skeletons from central Europe.²⁹ Perhaps these people learned about fermentation of milk from their trade contacts or descendants of Near Eastern immigrants. In other words, they used technological innovation to make this new food source available to them; any biological adaptations to raw milk consumption were consequences, not causes, of the adoption of dairy farming.

AGRICULTURE: ADAPTATION, STRATEGY, AND TRADITION

This has been a long chapter; however, there is much to say about the impact of agriculture on human diets, and much that had to be left unsaid. Despite these omissions, however, the larger picture illustrates in a compelling way how inheritance and innovation operate together to make foodways what they are. Looking at other life forms that have cultivated their own food reminds us that humans, too, occupy a web of ecological relationships in which natural selection is always at work. This is as true for us as it is for the ants that tend their fungus gardens,

despite the fact that we have a freedom to improvise that our distant invertebrate relatives lack. In both cases a kind of mutualism drives agriculture. For humans, this mutualism has consequences not only for genetic inheritance, but for cultural transmission as well; agriculture succeeds and spreads because farmers spread the word not only to their own children, but potentially to anyone they might come into contact with. The possibility of taking this novel way of making a living into new environments exists only because of our ability to innovate by applying existing knowledge to new circumstances.

However, all is not well for our early farmers, despite their big families and productive landscapes, for agriculture brings its own burdens. In exchange for knowing where our food is and having the means to manipulate plants and animals to suit our preferences, we have taken on great risks. Human populations can quickly grow to exceed the ability of the land to support them. Agriculture eventually became essential to preventing food shortage and starvation; crop failures that are due to disease or weather could be devastating for people with nowhere else to go. For prehistoric farmers, the shadow of famine was always present, waiting in the wings. New strategies were needed to keep it at bay and to combat malnutrition caused by monotonous diets of grain. How these strategies developed to buffer the risks that came along with the agricultural life is the subject of the next chapter.

5

HUNGER

They are gaunt with want and famine;
They gnaw the dry ground, in the gloom of wasteness and desolation.
They pluck salt-wort by the bushes
And the roots of the broom are their food.

Job 30:3–4

And let them gather all the food of those good years that come, and lay up corn under the hand of Pharaoh, and let them keep food in the cities. And that food shall be for store to the land against the seven years of famine, which shall be in the land of Egypt; that the land perish not through the famine.

Genesis 41:35–36

The danger of starvation hovers outside the awareness of those of us who are well fed. However, affluent Westerners are exceptional within the full scope of human history when it comes to food security. For many people, including our prehistoric ancestors, the future meals of tomorrow or next year can never be taken for granted; both periodic and unpredictable interruptions in food availability have long been a fixture of human life in most places and times. Wealth provides a buffer in societies in which inequality is institutionalized, protecting the privileged few. Even where privation is shared by all within a community, some habitats are blessed with such a bountiful and diverse resource base that times of famine are few and far between. However, seldom have people anywhere had the luxury of assuming that they would eat well very far into the future.

This chapter is about the difficulties of living with an unpredictable and variable food supply, and more important, about how people are

able to buffer or circumvent the most dire consequences of shortage. Our strategies are numerous; some, such as caching food against future bad times, we share with other cognitively agile animals. The habit of food hoarding has evolved independently among several groups of animals, including the hominins. Other mechanisms for coping with hunger are distinctively human, reflecting our unique capacity for invention and the stabilizing influence of cultural traditions. We have developed webs of mutual social obligation that allow human communities in different circumstances to take turns providing famine relief and benefiting from it. Even when obligations are absent or poorly defined, astute traders with access to food may be able to supply the hungry, provided that the latter have something else with exchange value. Within communities and societies, cultural traditions prescribe “famine foods” to be sought out when crop yields falter or fail, enjoin generosity (or frugality) when hunger threatens, and release people from normally strict avoidances of specific foods when the situation demands. These traditions are kept alive through good times by being incorporated into stories, songs, and myths.

FOOD SUPPLY IN A CHANGING ENVIRONMENT

The problem of food scarcity is not always to be solved by fixing the biotic environment – today’s famines have taught us that food supply is readily manipulated by people pursuing their own sociopolitical interests. However, the environmental fluctuations that make for a bumper crop one year and near-failure the next have had an impact on the availability of food long before mechanisms were in place to allow a powerful few to deprive the masses. Thanks to recent advances in physical and chemical science, we have the ability to probe past environments to find the causes of ups and downs in natural and agricultural productivity. Although these variables alone cannot explain fully why people adopted new food sources, sought out new habitats, or social institutions collapsed, periods of extreme drought or cold or excessive rainfall affected human communities by stressing the plants and animals on which they depended.

Both the periodic and predictable round of seasons and the unpredictable short- or long-term vagaries of the planet’s climate have shaped human foodways. Famines are impossible to predict with any accuracy, but a very different kind of food shortage is highly predictable, and therefore easier to plan for, because it arrives at about the same time

every year. Some element of seasonal variation, whether in temperature or rainfall or both, is present across most of the globe. Since hominins first confronted the problems of surviving in seasonal grasslands, seasonal variation in resource abundance has been a central concern of human food strategies. People, like many animals, are able to address seasonal shortages by shifting food around in space and time so that the surplus of one season can be used to augment the diminished supplies of the hunger season. They also have the option of moving themselves around on the landscape in order to intersect with the most productive spots as the seasons shift. Both storage and seasonal mobility have concerned archaeologists since these phenomena were first recognized, and both have archaeological correlates that have been thoroughly and systematically studied.

HUNGER IN NATURE

The discomfort of an empty belly is an inconvenience for larger animals, but the same perception can signal imminent starvation for a tiny shrew or hummingbird with a high metabolic rate. Between these extremes there is plenty of room for diversity in the effects that nutritional insufficiency have on an organism's survival and reproductive success. Whatever their target and magnitude, when such consequences exist, natural selection has an opportunity to reinforce successful strategies for coping with food shortage.

Periodicity and Predictability

Not all food shortages are alike. They vary along many parameters, ranging from brief to long duration, low to high severity, and from the regularly occurring (hence predictable) to the erratic.¹ Unpredictable shortages are the most difficult to prepare for; too little effort can have devastating results, whereas excessive forward planning wastes energy and time. Successfully balancing these tradeoffs is a challenge even for the most cognitively adept animals. In contrast, shortages that repeat at regular and recognizable intervals permit the evolution of less flexible responses that can be counted on to provide some appropriately timed relief. These strategies will be reinforced by natural selection to become stable elements of a species' dietary adaptation; there is little disadvantage to having such "built-in" components as long as the cycles of food availability are similarly locked in. Although spring may arrive early

or late, arrive it does as long as the Earth follows its path around the sun.

Severity and duration of food shortage are also important variables. When all food sources are equally affected, even the most catholic of menus will come up short. However, if some hardy plants survive a drought or a cold spell, animals with broad dietary tolerance – humans included – can take advantage of these less palatable, less nutritional foods. Some animals even eat their young, gaining needed calories and reserving resources for a future pregnancy in more promising times. Shortages of long duration sometimes call for desperate measures, such as abandoning the home range or territory and striking out for unknown but possibly greener pastures.

Strategies

One approach to food scarcity is to cut demand (as opposed to increasing supply). Some animals do this by reducing their energy budget during a period of hibernation (as in black bears), or estivation, its warm weather equivalent in wet-dry seasonal habitats. Others are more active and continue to feed, although they huddle together to conserve warmth and accumulate fat to help them survive the season of deprivation. However, there is an upper limit on how much fat a body can store and to what degree physiological processes can be shut down to conserve energy.

One way of overcoming these constraints is to shift food surpluses from times of plenty into hoards that can be held in reserve until needed. The two basic strategies of organizing hoards differ in whether they emphasize energy efficiency or risk reduction.² Scatter hoarding spreads out small packets of food across a broad area in space, requiring the animal to expend energy recovering each small cache. The advantage of scatter hoarding is that it limits the risk of losing an entire season's worth of stored food when a single location is discovered by a competitor. A gray squirrel may not be able to relocate all of its seed caches – some may, in fact, germinate and grow into oak trees that provision future generations. However, the probability that it will lose all its seed hoards is very low. The loss of energy devoted to storing seeds that are never recovered is usually offset by the low probability of losing everything. The squirrel's strategy follows the homely wisdom of the proverb that warns against putting all one's eggs in one basket. The alternative to scattering stored food is to keep it in a single location, as a sort of larder.

This approach limits the costs of traveling around to recover food caches and keeps losses down; however, larders must be defended rigorously, for their loss is disastrous. Keeping a single larder hoard may be more efficient than scatter hoarding, but it also carries a higher risk of dire consequences from theft by a competitor.

An alternative to moving the food around is to abandon one habitat for another. Some species have evolved migration strategies that are energetically costly, but relocate them to habitats in which they can successfully feed during the reproductive season. Migration to a new location is also a possible response to unpredictable, severe food scarcity for any reasonably mobile animal. However, migration is not a first line of defense against hunger, because it costs time and energy to travel to and perhaps conquer and defend a new territory.

Animals may migrate in groups, but few species make use of truly cooperative social means of coping with food shortage. Humans are the most notable exception to this generalization, but there are others. Vampire bats,³ much maligned in popular Western culture because of their eating habits (not to mention their gargoylelike faces), are one of the few animals known to engage in reciprocal food sharing. For these tiny bats, failure to feed can mean death overnight. Receiving a regurgitated blood meal from a group member will thus stave off disaster. Such systems are rare because the presence of cheaters who benefit without reciprocating quickly erodes the selective advantage of being a blood donor. For a vampire bat, cooperation in food sharing has such a powerful survival advantage that it outweighs the risk of generosity unrewarded.

HUNGER AND HUMAN SOCIETIES

We can detect parallels to many of these coping mechanisms in humans; these reflect both a shared heritage of behavioral flexibility in birds and mammals as well as the power of natural selection to hold onto successful solutions to the universal problem of getting enough to eat. However, people benefit from a more diverse toolkit for coping with food scarcity than other animals. We are unusual in having taken cooperative strategies for survival to an extreme level of development. Resource pooling, sharing, and long-distance exchange take the basic you-feed-me I-feed-you system of the vampire bats to a level of diversity and intricacy that humans alone seem to be able to sustain. When it comes to averting the worst effects of shortages that are unpredictable, sometimes severe,

and often of long duration, humans have a distinctive arsenal of coping mechanisms. We have an unusual ability to improvise behavioral solutions to food shortage problems in ways that have allowed us to populate most of the globe, from the arctic to the most arid deserts. Better still, we send these solutions on with our children and our children's children, not as a biological inheritance but as cultural information – the off-season recipes, tricks for stretching a dollar or a bushel of grain, or methods for building an insect-proof storage pit that allow people to endure the inevitable dietary downturns of an unpredictable world.

Hunger's Effects

Being large mammals, humans can survive for surprisingly long periods without eating. With just a small amount of food, people can lose up to 10 percent of their weight and still carry on their normal activities, at least for awhile.⁴ Even in a state of acute starvation, burning fat can sustain life for one or a few months. The human body has a few tricks up its sleeve for conserving energy – limiting activity and lowering metabolism, for example. But even with fat to burn, human endurance is not infinite. The stress of inadequate nutrition takes its toll, not only in the currency of psychological and physical pain, but in other forms that have more direct consequences for survival and reproduction.

The effects of the mother's nutritional status on the health of her infants are well documented.⁵ Even brief periods of malnutrition during pregnancy can impede cell growth in the developing fetus. Poor nutrition is one factor contributing to low birthweight of infants, a condition that has far-reaching consequences in later life and even into the next generation. The result is a continuing trend of small babies and high infant mortality.

Although maternal health is a crucial medium through which food shortage affects natural selection, it is not the only one. Nutritional stress increases susceptibility to disease, which, in turn, reduces the body's ability to absorb nutrients, a positive feedback loop that can have deadly consequences.⁶ Growth and stature are affected; people who experience poor nutrition do not reach their full genetic growth potential. Workers, both female and male, may have to curtail activities, further depriving them of essential resources. In extreme cases, social mechanisms of cooperation break down as each household tries to preserve its limited stores. Larger and more complex social networks of

cooperation, exchange, and domination can also be unraveled by the snowballing effects of food shortage.

Confronting Food Scarcity

As a species, we are vulnerable to severe or unpredictable changes in our environment, just like any other, but, arguably, we also have a particularly good bag of tricks available to meet those challenges. The distinctively human ways of managing two such strategies, storage and dietary diversification, serve to illustrate how technological expertise and culture enrich the toolkit for keeping hunger at bay.

STORAGE. Between 1912 and 1915, anthropologist Gilbert L. Wilson traveled to the Fort Berthold Reservation in North Dakota to collect data for his graduate thesis on traditional agriculture of the Hidatsa people.⁷ His chief informant, Maxi'diwiac (Buffalo Bird Woman), described to him the process of creating and filling a storage pit. First, mature corn was harvested and the cobs braided together by the husks before being allowed to dry. Dried squash and corn kernels were also placed into the storage pit. The pit itself was shaped like an inverted bowl, with a narrow opening to the ground surface. The floor was first lined with dried willow twigs and a piece of buffalo skin cut to the proper size. A particular type of grass, known to be resistant to mold, was dried and used to line the walls of the pit. Dried corn on the cob was stacked, narrow end inward, around the sides of the pit. Then came the shelled corn, poured into the center, and finally strings of dried squash in the very center, where it would be most protected from moisture. Once filled, the pit opening was covered carefully with layers of buffalo skin and grass. Wooden planks were laid down to prevent animals or people from falling into the hole, after which the pit opening was hidden to prevent theft when the village was abandoned in the winter.

As Buffalo Bird Woman's account makes clear, even without the tools of industrial technology, human craft takes the science of food preservation well beyond the simple behaviors of other mammals. The low-tech, but sophisticated, methods used to create the Hidatsa storage pits represent the cumulative knowledge of many generations of women in Buffalo Bird Woman's family, from whom she learned as a girl. She was not born knowing how to do this or ready to be "triggered" by some environmental stimulus to produce the appropriate behavior. Learning takes time and effort; however, the payoff is a degree of flexibility that

allowed Buffalo Bird Woman to tweak and improve an already finely tuned body of knowledge before passing it on to her own younger female relatives.

Subterranean storage pits like the Hidatsa example are familiar to most archaeologists, wherever they work. Although they are common in many locations and time periods, storage pits may be difficult to differentiate from pits excavated for other purposes. This is true because there are physical constraints on the size and shape of any pit excavated into the soil and because its original contents are usually long gone, replaced by refuse or natural deposits after its usefulness has ended. However, a carefully excavated pit can yield clues as to its function. Depending on conditions affecting preservation, a storage pit may retain remnants of materials used as a lining, such as bark or grass. For this purpose, traditional storage methods often appropriate the pesticidal or antibacterial properties of plants. The form of a pit is also relevant: If designed to store nuts or grains, it should have an opening at the surface large enough to allow access to the interior, but not so large that it invites entry by rodents or other seed predators (access is not an issue if the pit's contents are meant to be removed all at once). The resulting bell-shaped pit is a common design in North America and elsewhere.

Storage pits are limited in volume, so large communal facilities generally move aboveground in the form of cribs, silos, or special rooms. The latter are identifiable by their size (usually too small to be a living or sleeping space) and sometimes their contents, depending on preservation. Within a region, the characteristics of storage rooms become well known, and sometimes they have ethnographic analogs. The prehistoric great houses of the southwestern United States have small storage rooms, as do the Neolithic clay brick villages of the Near East.

The Hidatsa storage pit is only one example of a vast array of techniques developed by people all over the world to facilitate time shifting of food. Whereas the foods themselves and environmental conditions vary, processing techniques to extend shelf life obey the same laws of chemistry. All are designed to exclude or discourage organic competitors – molds, fungi, insects, and pilferers of the four-legged variety. The physical form of storage facilities depends on the need for concealment, whether stores are accessible to the community as a whole or a single household, and the physical characteristics of the food itself.

Food storage by humans has essentially the same goal as hoarding by squirrels: to create energy reserves that can be used to bridge seasons of low natural productivity. Storage is, in fact, ideal for buffering

annual periods of shortage, which are predictable and relatively brief. Unanticipated or lengthy periods of low production may well exceed the ability of storage to forestall hunger. Under such conditions, farmers and hunter-gatherers alike turn to foods not normally part of the diet because they are unpalatable, culturally proscribed, or costly to process – the famine foods. These resources can be key to survival for farmers whose crops fail for multiple years, provided that people know how to find and prepare them. Maintaining that knowledge is crucial if famine foods are to be of use.

DIVERSIFICATION OF DIET: FAMINE FOODS. The logic of optimal foraging theory predicts that being choosy about what one eats is inefficient when the top tier of resources is scarce. This tendency may be the microeconomic engine behind the shift to broader diets in many parts of the world during the Late Pleistocene (see Chapter 4). This kind of adjustment can serve to relieve hunger no matter what the reason for the shortage of preferred foods – a season of dormancy, perhaps, or an unexpected drought. Expanding the list of potential foods is effective in that it keeps calories coming in, although it does entail some loss of overall efficiency compared to other backup plans, such as food storage. However, the main advantage of expanding the roster of foods is that it can be implemented on short notice as the need arises.

For this strategy to work, people need to know what plants and animals they can turn to safely in difficult times. They need to have knowledge of the natural world beyond the cultivated field and the dooryard garden, especially of those hardy species that can endure the same conditions that cause crops to fail. Famine foods are ones that contend with environmental stressors such as drought and disease by defending themselves with barriers both mechanical and chemical. They survive difficult conditions because they have spines, rinds, thorns, and unpalatable or toxic chemicals. For this reason, famine foods often require special handling if they are not to cause more problems for human health than they solve. Therefore, the cultural knowledge needed to process such marginal foods must somehow be retained even during times of prosperity when they are not needed, if they are to serve during times of deprivation when they may be essential to survival.⁸

Knowledge of famine foods does persist, even when it is not of immediate utility, as an ingredient in oral tradition.⁹ People who do remember times of hunger tell their stories to children and grandchildren. Tales told for entertainment or as part of sacred literature become receptacles

for knowledge of how to forage for wild foods when crops fail. In this way, even seldom-used information continues to circulate within the pool of cultural knowledge, much like a genetic variant whose effect on the organism lies dormant until elicited by some environmental trigger.

In places where food availability fluctuates with the cycle of the seasons, knowledge of famine foods tends to be persistent because it is applied on a regular basis. Seasonal food shortage is, therefore, one means by which such information is preserved across generations. In the arid southwestern United States, the contents of desiccated human feces dating to between AD 1100 and 1300 contain remnants of many plants now considered to be famine foods.¹⁰ Although maize and squash were the most common foods consumed, they were often accompanied by less nutrient-rich plants that could be found in the wild: Weeds such as goosefoot (*Chenopodium*), pigweed (*Amaranthus*), prickly pear (*Opuntia*), and different types of cactus were all eaten on a regular basis. The small quantities found indicate that they were not of great dietary importance and yet seem to have played an important role in bridging the gap between growing seasons. In more recent times, seasonal hunger has been buffered by the greater availability of purchased food, and knowledge of these lesser-known plants has dwindled. In the prehistoric past, however, the seasonal cycle helped to keep such knowledge available for more serious and less predictable threats.

When people are facing starvation, they are often forced to put aside not only personal and traditional preferences, but cultural prohibitions that under normal conditions would be powerful disincentives. Less preferred foods give way to articles not normally considered food at all – shoe leather, cereal chaff, clay, anything that harbors organic content, however minute the quantity. Food taboos may be set aside when circumstances are dire, without supernatural or social penalties being imposed. However, there is one line that, once drawn, is almost never crossed – the boundary between being human and being food. This dichotomy is far from universal, but where it does exist it is powerful and seldom transgressed.

Cultural beliefs and attitudes regarding cannibalism – or anthropophagy, a more neutral term – vary widely. Where it is (or was) a culturally acceptable or prescribed practice, eating human flesh is variously perceived as a way of honoring the dead or of humiliating one's enemies. Casual dietary cannibalism appears to be rare, although there are reports of human groups that practice it without any ritual trappings.¹¹ It might be difficult to sustain this practice, however – society is apt to

change in some radical ways when your neighbor is both a potential ally and a potential meal. At the other end of the spectrum, cultures with European roots abhor the practice, which is both illegal (abuse of a corpse) and regarded as disgusting in the extreme. However, anthropophagy is condoned in exceptional circumstances such as imminent starvation. Thus, the victims of an Andean plane crash in 1972 who consumed the frozen flesh of their dead companions to stay alive were popularly seen as heroic rather than deviant.¹²

Despite claims that accusations of cannibalism were a ruse of Western imperialists intent on discrediting indigenous peoples, the many ethnographic and ethnohistoric accounts are impossible to ignore. Even more compelling as evidence that cannibalism is a real phenomenon is *kuru*, a fatal neurological disorder similar to Creutzfeldt-Jakob disease, the dreaded mad cow disease. *Kuru* is a disease caused by prions, which are rogue proteins in the brain that change their configuration in ways that cause destruction of brain tissue. *Kuru* was first documented among the Fore and other New Guinea tribes who practiced mortuary cannibalism (in which dead relatives are consumed as part of the mourning process).¹³ It was found that the prions that caused *kuru* were transmitted from the brains and nervous tissue of the deceased to participants in funeral feasts, who were usually women. Oral and medical histories, thus, clearly support the reality of cannibalism in modern times.

The prehistoric past has yielded evidence of anthropophagy as well, the earliest claims of which date to before *Homo sapiens* was on the scene.¹⁴ Many have been examined and dismissed because other causes of the observed patterns (such as cut marks and charring on human bones) could not be ruled out. It makes sense that the criteria for identifying archaeological cases of anthropophagy are rigorous, not only because it is good scientific practice but also because of cultural sensitivities among descendant populations (the claim that one's ancestors were cannibalistic is not likely to be greeted with enthusiasm). A determination that an assemblage of human bones is a product of anthropophagy must, therefore, rest on traits unique to that activity. Cut marks and other signs of dismemberment are not sufficient, because bodies may be cut up for burial, cremation, or some other special funerary treatment. If cut marks are accompanied by burned and fragmented bones discarded with or in the manner of nonhuman animal food refuse, a stronger case can be made for cannibalism. Even more compelling is pot polish – shiny abrasions that can be produced when bones bounce around in a ceramic container while boiling.¹⁵

All of these criteria, and more, apply to one of the most thoroughly documented cases of anthropophagy from the site 5MT10010 in southwestern Colorado.¹⁶ Located in Cowboy Wash, this small cluster of houses and associated features was occupied sometime around AD 1150, during the Pueblo III period. Two of the houses contained the remains of seven individuals whose bodies had been dismembered and defleshed – there were even two stone flakes that retained traces of human blood. Some had been roasted, judging by the condition of the bones. These people were not buried; instead, their body parts were left scattered on the ground. Together, these pieces of evidence make for a compelling, if circumstantial, case for a cannibalistic meal. But there is more. Very direct evidence of the consumption of human flesh came from the third house, which contained only a few fragments of human bone. Its central hearth contained a single human coprolite – preserved feces. Testing revealed that the coprolite contained human myoglobin, a protein found only in human skeletal and heart muscle. There is only one logical conclusion that can be drawn from this find – that someone defecated inside the house after having consumed human flesh.

It happened something like this. Two, perhaps three adult males, two adolescents, and one child lived in the small homestead. If they produced any maize in Cowboy Wash, they did so only with difficulty and with the help of irrigation. In any case, they ate little of it, subsisting mainly on a wide variety of wild plants. It was late winter or early spring when the massacre occurred, a time of food scarcity even in the best of years, and everyone was hungry. So were the strangers who attacked and killed them. Although its precise cause cannot be determined from the bones, death was violent and probably quick. The intruders killed their victims, butchered, cooked and ate them, leaving behind piles of broken human bones and defecating on one of the hearths as they left. They then abandoned the site without taking any valuables.

Who committed these acts of violence, and why? There is no reason to think that cannibalism was practiced by local populations on a regular basis at any time in the past. The relatively few incidents that have been documented are not randomly distributed in time; all occurred around the same time as the Cowboy Wash massacre and coincide with a well-documented drought in this part of the Southwest (discussed further in the following section). This correlation suggests, although it does not prove, that hunger-related stress played a role in the attack. Whatever the immediate psychological motivators may have been,¹⁷ this act of cannibalism hints at the ramifying (and destructive) effects of

food scarcity on culturally transmitted values and the social behaviors they inform.

Vulnerability to Food Scarcity Among Foragers and Farmers

Agricultural societies have a special vulnerability to unanticipated shortfalls arising from droughts or freezes or other uncontrollable natural events. To understand why, recall that populations of farmers have the potential to grow considerably larger than the hunter-gatherers with whom they coexist. There are a number of reasons for this pattern. One is that women who remain closer to home are more likely to have many children, who often become an important part of the household labor force. Despite high infant and child mortality, over a lifetime women farmers are likely to have more surviving children on average than their foraging neighbors. More people can be supported on an acre of land through intensive production than on an acre that is managed only lightly or not at all.

What would seem to be an inevitable success story for cultivators and herders is marred by the fluctuating nature of the weather and other environmental influences on crop and livestock production. There is little to constrain population growth in prosperous times – unlike mobile hunter-gatherers, whose lifestyle keeps families small even when food is abundant, agriculturalists can accumulate children. Large families can be well sustained given ample production of grain, dairy products, root crops, or other staples. But when crops fail for several years in a row, or even longer, the children of prosperity are at risk of starvation. They cannot support themselves by foraging, at least not at the same population level as before, and may have lost some of the cultural knowledge needed for expert hunting and gathering. And in a landscape beginning to fill up with farming communities, moving to a new village site may be impossible. So whereas food production allows human communities to grow, it also places them at risk of catastrophic failure when food shortages occur.

Because of these differences, hunter-gatherers and farmers tend to follow somewhat different strategies for staving off or successfully surviving food shortages. Farmers generally find it more difficult to move, because of the lack of unoccupied cultivable land and their investment in existing houses, public buildings, and equipment that are cumbersome and costly to transport. Instead, farmers usually diversify by planting multiple crop varieties, dispersing their fields to occupy

different microenvironments, thereby creating a diversified portfolio that is unlikely to result in a catastrophic loss. This approach is robust and sustainable. Tragically, however, there are times when environmental extremes exceed the ability of diversification to prevent harvest failures. When crops provide the bulk of the food supply for a complex and hierarchically organized society, reduced yields or outright failures can bring an entire population perilously close to famine. Societal collapse, or drastic reorganization on new terms, is often the result.

CLIMATE, CROPS, AND HUMAN SOCIETIES: TWO TALES FROM ANCIENT AMERICA. Some of the most thoroughly studied cases of cultural collapse that were due to agricultural failure come from the Americas. Perhaps the effects of sequential years of bad weather were particularly devastating for economies that lacked both domesticated food animals and sufficient wild resources to sustain long-term crop failures. Two such cases have become reasonably well understood through the efforts of archaeologists and other specialists who have tried to pin down the causes of catastrophic social collapse. Although these causes are many and intertwined, ruling out simplistic explanations, they seem to be closely connected to the failure of agricultural production to feed a population already close to the environment's ability to sustain it.

The Maya civilization of Central America has earned itself a prominent place in the public consciousness, in large part because of its spectacular material remnants in the form of paintings and pyramids, the carved monuments known as stelae, elaborate glyphs that record important events, and a calendar that incorporated three different methods of reckoning time. These prominent examples of Mayan aesthetic and intellectual accomplishments come from the urban centers of the Classic period (AD 600–900), which were architecturally elaborate and the focus of ritual and dynastic activities. The precise nature of Mayan rulership is still debated by archaeologists; however, it was clearly not a centrally governed and unified state but rather a loose confederation of capitolis constantly vying for supremacy. Mayan rulers ascended and descended – sometimes precipitously – as war and commerce altered the political landscape. The great events celebrated in stelae, however, are only one part of the Mayan story. Most of the population lived dispersed across the countryside making a living by growing corn, beans, squash, and other crops. Their descendants continue to farm there today, from the Yucatán Peninsula to the highlands of Guatemala.

The Maya area stretches from the northern tip of the Yucatán Peninsula southwestward to the ridge of highlands that run north–south along the Pacific coast (Figure 2.1). The Maya lowlands, where the highest concentration of Classic period sites are found, presents significant challenges for the farmer. Access to water is often difficult, particularly in northern Yucatán, whose karstic landscape consists of a flat expanse of eroded limestone in which streams tend to disappear underground. Although surface water is easier to come by in the southern lowlands, throughout the region rainfall is highly seasonal, falling mostly in the summer months.

The rural farmers of the Classic period were in intimate contact with the annual seasonal cycle. They would have been the first to know when the rains failed to come and the maize began to turn brown in the fields. Multiple lines of evidence tell us that such periods of drought were frequent, severe, and long-lived during the prehistoric era during which the Maya and their predecessors were developing their distinctive culture.¹⁸ This is not surprising, given the location of parts of the Maya area along the northern edge of the usual path followed by the tropical monsoon rains. It is these monsoon rains that the Maya people relied on to bring their maize and other crops to fruition. However, sometimes the path of the monsoons shifts southward, causing the rains to bypass the region entirely. This happens because of fluctuations in the system of air circulation known as the intertropical convergence zone (ITCZ). In this circulation pattern (Figure 5.1), the rising air of the ITCZ creates summer rains in the monsoon zones, including northern Yucatán. As it ascends further, the ITCZ generates the year-round rains that support the equatorial rain forest. On the way down along the outside of the two circles, the descending air of the ITCZ produces virtually no rain, and it is here that the world's deserts are situated. Finally, before completing the cycle, the descending air moves again into the monsoon region, keeping the winter months dry.

The vulnerability of much of the Maya area to drought derives in part from its position on the northern edge of the monsoon zone. A small shift of the ITCZ to the south diverts the monsoon summer rains southward as well, replacing them with descending dry air year-round. This is what seems to have happened several times during the Mayan era, but most notably between AD 800 and 1000. What happened at the end of the Classic period, around AD 900, was a transformation of Mayan society so far-reaching that archaeologists refer to it as a collapse.

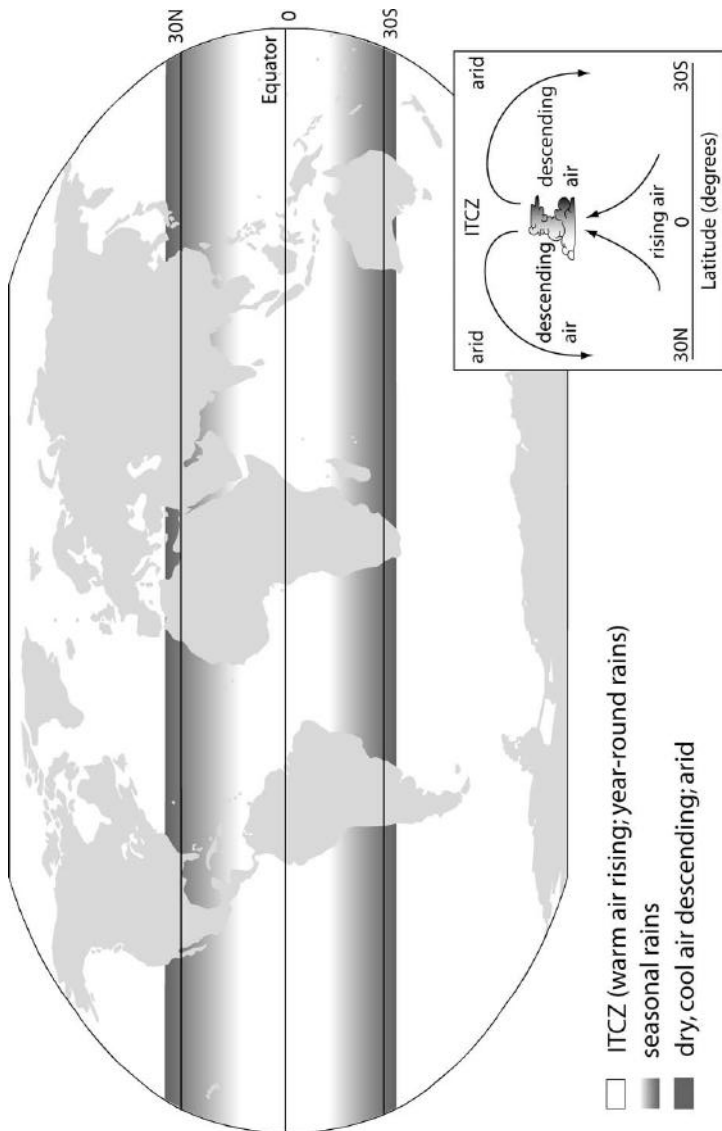


FIGURE 5.1. The intertropical convergence zone (ITCZ). This equatorial band of rain clouds is part of a circulating cell that rises near the equator carrying warm, moist air upward, where it generates heavy rainfall in the humid tropics. The rising air then becomes dry as the circulation pattern carries it back to the equator, releasing little or no rain over the earth's deserts. The annual migration of the ITCZ north and south of the equator creates seasonally wet/dry climates. When the ITCZ deviates far from its usual path for several years in a row, it can deprive the wet/dry tropics of rain, causing crops to fail.

Although the debate over what caused the Classic Maya collapse is ongoing, new techniques have made it possible to pinpoint with great precision the times during which drought had its greatest effect on Mayan agricultural production. One such method involves the measurement of titanium, an element whose concentration in sediments varies with the amount of fresh water influx. These measurements cannot be taken just anywhere; the sampling sites need to be isolated enough to record accurately the quantity of sediments derived from a single source, such as a river. These conditions are met in the Cariaco Basin of Venezuela, which, despite being located on a different continent, experiences the same weather systems as the Mayan area. The sediment samples from the Cariaco Basin accumulate titanium in direct proportion to the influx of water: High titanium indicates large quantities of sediment being washed into the basin, whereas low titanium results from drought conditions. Titanium levels in the Cariaco Basin were determined for intervals of two months using a specialized type of X-ray fluorescence, which bounces X-rays off a sample to measure its elemental composition. Even finer chronological resolution was obtained by reading the alternating bands of light- and dark-colored sediment that represent dry and wet seasons respectively. The results indicated four periods of multiyear drought around AD 760, 810, 860, and 910. These dates may not be precise, because of the high error margin of radiocarbon dating, although they are probably close. Multiyear droughts may well have been the last straw for a system already under considerable stress from the “megadrought” that afflicted the region between AD 800 and 1000.

Titanium levels and sediment layering are not the only sources of data to indicate repeated droughts coinciding with the Classic Maya collapse. Periods of low rainfall have been documented from the Pacific coast of Guatemala eastward to the Yucatán Peninsula using other elements and compounds as proxies for rainfall, as well as concentrations of different types of pollen and phytoliths that record past vegetation. All of these measures converge on the conclusion that droughts played a role in shaping the fortunes of the Maya, although opinions differ as to the importance of drought and crop failure in destabilizing their complex sociopolitical system as the Classic period drew to a close.¹⁹ Certainly many other variables were at work, including deforestation resulting from intensification of agricultural production to feed a growing population, and internal social and political conflicts.

It is one thing to claim that drought and crop failure resulted in societal collapse, and quite another to specify how the breakdown in the

food supply actually affected people and families on a daily basis. One year of lower than normal yields might be overcome at the household level by eating what was stored the previous year, leaving enough to plant the next season. A few years of poor yields might be offset by drawing on central grain storehouses maintained by rulers. However, by this time, the situation would be dire. Many, perhaps most, of the nonelite population would be in a state of semi-starvation or malnutrition. Desperate people turn to theft and violence in order to survive. It is easy to imagine how social institutions would have lost their ability to maintain orderly relations among the citizens.

Several hundred years after the events that transformed the Maya world of the Classic period, the impact of drought was to be felt in the arid Southwest of the United States.²⁰ At the center of the Four Corners region lies the meeting place of four states – Arizona, New Mexico, Colorado, and Utah. Here, on the Colorado Plateau, the ancestors of modern Pueblo peoples – known today as Ancestral Puebloans and as the Anasazi in older literature – established substantial communities supported largely by maize agriculture. The D-shaped ruins of Pueblo Bonito (Figure 2.1) are a classic and well-known example of ancestral Pueblo architecture between AD 950 and 1100. Pueblo Bonito and other masonry “great houses,” each consisting of hundreds of rooms, were linked together by a network of roads. Archaeologists refer to this larger social network as the Chaco phenomenon (named for Chaco Canyon, where Pueblo Bonito is located). After AD 1100, there are signs that the Chacoan system was under stress, and after AD 1150 it seems to have broken down entirely. Based on the number of archaeological sites, the human population of the Four Corners area declined precipitously after AD 1130 and again after AD 1280. By AD 1300, the Colorado Plateau had been largely abandoned by farmers, although it continued to support smaller hunter-gatherer groups.

In the case of the Chaco collapse, drought is once again a major (although surely not the only) culprit. Evidence continues to mount that the Four Corners region experienced severe, multiyear droughts several times between AD 1000 and 1300. These dry periods can be very precisely identified thanks to the well-preserved structural wood found on many sites in this arid region. Woody plants experience a growth spurt each year in temperate climates that causes trees to expand in girth; the larger the diameter of the trunk, the older the tree (provided that you are comparing trees of the same species under similar growing conditions). It is this pattern of growth that create the rings that can often

be seen easily in a cross-section of a branch or trunk. Tree rings have a particular significance for archaeologists because they carry a year-by-year record of environmental conditions reflected in the width of the rings. Poor conditions, such as unusually low rainfall, limit growth and create relatively thin rings, whereas ample rain and optimal temperatures encourage cell division, resulting in thicker rings. Each ring corresponds to a specific year that can be determined by counting backward from the present. Thus, it has been possible to pinpoint several intervals when growth was constrained by drought – AD 990 to 1060, 1135 to 1170, and 1276 to 1297. Note the close correspondence of two of these droughts to the population declines of 1130 and 1280.

Like the Maya, the Anasazi people experienced periods of population growth during favorable conditions for maize production, growth that was not sustainable under a highly variable rainfall regime. The Ancestral Puebloans did what they could to maximize and conserve the water supply by using mulch and constructing channels to divert water to the fields before it could evaporate or percolate down into the dry soils. However, these efforts were not enough to overcome the effects of so many years with little rain. Even in good years, it is likely that no more than a year's supply of maize could be stored for later use. Some communities seem to have relocated to areas where rainfall was more reliable, whereas others may have adopted a more mobile way of life that was less dependent on agricultural production. Like the Maya, the Ancestral Puebloans were forced to reorganize socially and economically under conditions of persistent food scarcity.

AGRICULTURE AND MALNUTRITION: THE CASE OF MAIZE. The Maya and the Ancestral Puebloans are not the only ancient societies that illustrate the special vulnerabilities of food producers to the bait-and-switch tendencies of variable environments. Agriculture permits growth of human populations to levels that cannot be sustained during periods of scarcity. However, this is not the only hazard to human nutrition that comes with the transition to food production. Even when food supply is adequate to provide sufficient energy for growth and reproduction among all segments of a society and to produce surplus for trade and storage, not all calories are created equal. It is often the case that farmers pay a high price for ample production in the form of loss of dietary diversity. Specialization in one or a few crops may cause less productive foods to fall by the wayside, many of which provide important nutrients even though they cannot match food crops as an efficient source of energy.

The health consequences of a nutrient-poor diet are particularly severe when maize is the staple crop. Low nutritional quality of maize is further compounded by its ability to interfere with the absorption of iron consumed from other sources (see Chapter 4). Heavy reliance on maize was the culprit responsible for the deteriorating health of many prehistoric populations in the New World as they made the transition from forager to farmer. In severe cases, the traces of these nutritional pathologies remain in the bones and teeth recovered and studied by bioarchaeologists (anthropologists who specialize in the study of human remains from archaeological sites). The story they tell is one that seems paradoxical – maize-fed farmers of the Americas often experienced declining health compared to their foraging ancestors, even though they were able to support larger families.

The biological impacts of a maize-dependent diet are amply documented in the midwestern and southeastern United States, where maize became a staple around AD 1000, largely replacing native seed crops and nuts as the primary source of carbohydrate calories. What bioarchaeologists have found is that maize dependency had negative effects on health in many populations.²¹ For example, post-AD 1000 burial populations often show signs of stress during childhood more frequent or more severe than those experienced by their forager (or forager–farmer) predecessors. Episodes of stress early in life are recorded in tooth enamel as linear defects that form as a result of interrupted growth. Similar stress-related defects can be seen in long bones such as the femur (thigh bone). Such growth interruptions sometimes result from seasonal scarcity of food energy or specific nutrients that affect foragers and farmers alike. However, women of farming communities are more likely to wean their children sooner and perhaps more abruptly than their forager counterparts because of the ready availability of easily digested – but nutrient-poor – transitional foods such as cooked or pre-chewed cereals.

Another growth anomaly that differentially affects agriculturalists is porotic hyperostosis – a spongy condition that develops in certain bones of the skull and eye sockets. It is caused by iron deficiency anemia, one common consequence of heavy maize consumption (maize is very low in iron to begin with and contains compounds that inhibit iron absorption). Porotic hyperostosis is not a foolproof indicator of heavy maize consumption because anemia can result from parasites and other stressors that interfere with the metabolism of iron. However, it often corresponds well with other indicators of reliance on maize or other

grains – tooth decay, for example, and the charred remains of cobs and kernels recovered from refuse deposits.

The failure of Maya and Ancestral Puebloans efforts to maintain stable systems of food production appear to paint a grim picture of human hopes for long-term agricultural sustainability. Even reliable production of crops is no guarantee of a nutritionally adequate diet, as the often poor health status of prehistoric maize farmers indicates. But death, disease, and social upheaval are only one side of the coin; after all, we are still here (at least for now).

FIGHTING HUNGER: CULTURE AND CREATIVITY

Animals of all kinds, including humans, face fluctuations in food supply. Seasonal variations are common, and many species have evolved anatomical, physiological, and behavioral adaptations that help them to survive these annual periods of food scarcity. An effective way to do this is to create hoards of food during times of abundance that can be accessed later. When people do this, we call it storage. But humans put their own distinctive spin on the food hoarding strategy, using a variety of treatments that extend shelf life. When storage fails to provide enough, or when unanticipated shortages occur, humans are able to seek out a variety of strategies – sharing, trading, or pooling foodstuffs, moving to richer habitats, or diversifying. The simplest version of the latter is to reduce selectivity and eat foods that are usually bypassed because they are expensive to capture and process, have low nutritional value, or both.

Cultural transmission of information is a valuable adjunct to the expansion of dietary variety, because it reduces the hazards of guessing which alternative foods are safe to eat and which need to be processed first. Oral traditions keep such knowledge current even through prosperous times when it might otherwise be forgotten. In this way, strategies for keeping hunger at bay are maintained by tradition without being set in stone. For agriculturalists, the risk of falling short of food can become high if good conditions for crops – which allow population growth – are followed by catastrophically bad years. The consequences can destabilize entire social systems.

However, people eat, not social systems. When we look inside those systems, especially ones with a hierarchical form of social organization, we see that not everyone eats the same way. Social rank influences diet in

ways that archaeologists can study through material remnants of food, dishes, human tissues, and depictions of meals. The haves and have-nots within a stratified society are likely to consume different foods, with consequences for their health and ability to raise children. These differences are symbolized in the rituals of eating, many of which leave archaeological traces. Some of the most symbolically rich behaviors involve the most nutritionally impoverished comestibles – alcoholic beverages. If we look carefully, we can identify social inequality in differential access to foods like these, some valued because they are mind-altering, others because they are rare, expensive, or particularly important to human health.

6

ABUNDANCE

There is sublime thieving in all giving. Someone gives us all he has and we are his.

Eric Hoffer, *The Passionate State of Mind*

This was a good dinner enough, to be sure, but it was not a dinner to ask a man to.

Samuel Johnson, quoted in Boswell's *Life of Johnson*

That hunger elicits coping strategies is hardly a surprise; after all, survival of the individual, community, or even population is at stake. Responses to scarcity of food have easily recognizable consequences for the organism, and thus for survival and reproductive potential, the engine of natural selection. The impact of hunger on the social realm is perhaps more complex and less easy to discern; nonetheless it is easy to accept that food supply is a key material factor influencing the rise and fall of higher order sociopolitical units such as states.

But what are the consequences of how we cope with abundance? There is no stressor here, but rather a set of opportunities. How a household or a state invests its surplus food may seem not to matter very much, at least in contrast to the potential effects of a food shortage. However, the investment opportunities associated with abundance do have consequences that matter, both for future survival (as in the case of storage) and for the development of social inequality based on wealth and control of resources. Food in excess of immediate dietary needs can also be mobilized for display in the public arena as an indicator of wealth, power, or status of an individual or group, or to mark important rites of passage. When food surpluses – or foods that are highly esteemed – are concentrated in the hands of the elite members of society,

the less fortunate often suffer health deficits as a result of inadequate nutrition.

Interpreting the material record of food distribution and its consequences for diet, health, and social dynamics is a major challenge for archaeologists. Food refuse, artifacts, and human bones offer pertinent information on what people ate and how they procured, prepared, and consumed it. However, the social context in which these activities took place is more elusive even than the basic facts of who ate what. Few traces remain of intangibles, such as seating arrangements, rituals, speeches, or ceremonial sharing of beverages. Large communal meals with great cultural significance may be marked by unusual quantities or type of food processed in public settings; however, we often remain in the dark about whether feasts were competitions between political rivals or communal celebrations of key transitions – marriage, the first harvest of the year, a death. Written records help us to fill in some of these missing details, or at least lead us toward plausible interpretations that can be tested against archaeological data. Even then, our best efforts will leave some questions about the social roles of surplus food. Commitment to a scientific approach to knowledge demands that we accept that there will be gaps in that knowledge that we may not be able to fill.

These methodological challenges highlight the fact that humans handle surplus food in many ways that are unusual in the natural world, in part because they have such a strong symbolic component. Food does not just communicate information in human societies; it has meaning. Nevertheless, there are some parallels in the way that humans and other animals respond to unusual abundance. These parallels are worth a closer look because they can help us understand the deeper roots of behaviors that mobilize extra food, such as storage, competition for marriage partners and social influence, and food sharing.

ABUNDANCE IN NATURE

How often do animals other than humans experience a superabundance of food? Windfalls are bound to happen from time to time in response to favorable environmental conditions. Optimal values of key variables such as rainfall and temperature support plant growth and reproduction, and the consequences of this primary productivity ramify up the food chain to omnivores, herbivores, and ultimately carnivores. Having plenty of high-quality food has obvious advantages for animals:

Adequate nutrition, lower expenditure of energy in the food quest, and the biological resources to support offspring all contribute to reproductive success. But what good is more than enough? All animals, humans included, have limits on how much they can consume at one time and how much they can store as body fat. Beyond these limits, food must be stored outside the body if it is to be useful to the animal at a later time.

Food storage shifts nutritional benefits from times of superabundance to times of scarcity. Storage is, therefore, most advantageous in seasonal climates. However, animals may also store food to carry them through times when normal feeding cannot be carried out because of time constraints, for example, during the breeding season or when the risk of being eaten by a predator is too high to risk a foraging trip. Food storage in birds and mammals is most commonly found in species that rely on seeds and nuts, but it is not limited to them; even some carnivores will store a fresh or partially eaten kill when they are not able to consume it all at once. Storage of animal prey is developed to a high art by shrikes, which keep larders of insects and other small animals impaled on thorns until feeding time.¹

If not stored, leftovers are likely to go to waste once the animal is satiated. The alternative is to share, or at least allow others to consume the remnants of a partially eaten meal. Because food that cannot be consumed has no utility for the individual who possesses it and furthermore takes time and energy to defend, this practice has been labeled “tolerated theft” by behavioral ecologists. The donor incurs no cost, and the recipient gains a significant benefit, so it is no surprise that tolerated theft has found a place in the behavioral repertoire of many social animals.²

Sharing that does incur some cost for the donor is not so common, because if there is no compensating benefit, generosity should be kept in check by natural selection. Individuals that give food away to nonrelatives and receive nothing in return are not likely to prosper and pass this behavioral disposition on to their own offspring. However, there are sometimes hidden benefits that may not be apparent to the short-term observer. Some food sharing is reciprocal, as in vampire bats (see Chapter 5). However, the conditions that make this system effective are rather unusual. In most species, the potential for “cheating” (taking food but not reciprocating in kind) is considerable and places constraints on the persistence of reciprocal food sharing. Cheaters will gain benefits they did not earn, and individuals who play by the rules must either be

taken advantage of or spend time and energy to punish cheaters. The dilemma created by the so-called free rider problem probably cuts short the development of reciprocal sharing in many animal species.

Reciprocation, however, need not be deferred until some future time, nor does it have to take the form of food. Copulation is another possible payoff, one that males rather than females are willing to accept. This difference between the sexes exists because in most species, females potentially invest more in a single mating than do males. If the female nurtures young without male help, she is likely to be more choosy about mates than are males, who have nothing to lose except sperm. When males must compete for mating opportunities, they are likely to evolve behaviors that provide material assistance to the female, or communicate to the female that they are good prospects.

Feeding the female a special “nuptial gift” or simply providing her with her usual type of food is one way of standing out from the crowd of potential suitors. Provisioning the female before copulation either provides her with needed energy or communicates that the male has the parenting skills to help raise offspring to maturity. In many spiders, the male pays the supreme price for reproducing when he offers himself as the nuptial gift once fertilization has taken place. Presumably in these species self-sacrifice on the part of the male yields more offspring than alternatives – offering insect prey, exuding a nutrient-rich substance, or simply running away at the first opportunity. These less extreme options work well in many animal species, in which the male walks away from the encounter having exchanged food for a chance at reproducing – and lives to seek another partner.

When direct benefits in the form of nutrients are not part of the mating routine, how is a female to choose? She generally has fewer mating opportunities than her male counterparts, because of the demands of nurturing eggs and sometimes caring for young; therefore, she is likely to be much more selective than they are when it comes to choosing a mate. If the males are expected to help raise offspring, they may prove themselves by provisioning, nest-building, and other relevant activities. However, if they are destined to be absentee fathers, other qualities are more important. Because genes are hidden, any cues must be part of the male’s phenotype – his appearance, behavior, or other outward and perceptible features that might be indicators of the ability to produce quality offspring (quality in this case being relative to the challenges presented by the environment).

What should a discriminating female look for? The specifics vary depending on environment, but robust health, strength, ability to defeat other males in fighting are all reasonably good indicators of a genetic heritage free of serious flaws and may also predict vigorous offspring. There are less direct ways to communicate quality of phenotype (and, by implication, genotype). Males sometimes engage in behaviors that fall into the category of “costly signaling” – that is, they communicate their quality as mates by doing something difficult and doing it well even under adverse conditions. Whether they consist of elaborate tail feathers or a courtship “dance,” these adornments or behaviors are difficult or impossible for less well-endowed individuals to fake. Because they are costly, only the animals with resources to spare can pull them off. Providing food at considerable expense to oneself is one method of sending such a costly signal. Because it influences the female’s choice of a mate, food provisioning plays its role well as a signal regardless of whether the food is consumed.

In nonhuman primates, food may be either contested or shared, depending on the species and the circumstances. Among chimpanzees, extensive sharing between unrelated individuals is not a common occurrence. However, food gifts are sometimes offered by males in pursuit of sexually receptive females. Perhaps more significantly as a clue to the possible role of specially valued foods in human societies, chimpanzees share meat. When a chimp (usually male) captures prey (usually a young colobus monkey), the meat becomes the centerpiece of an extended session of intense social interaction. The details of this bout of sharing vary from one chimpanzee population to another. In the Tai Forest of Côte d’Ivoire, the kill is shared among all individuals present, regardless of whether they are capable of reciprocating, or likely to do so. However, the chimpanzees of Gombe in Tanzania, made famous by the pioneering research of Jane Goodall, share their kills in ways that strongly suggest that they are manipulating social relationships – securing sex partners or strengthening some alliances and neglecting others.³ Males contesting for social dominance, thus, use a particularly valued food – meat – to fuel their ascent in the status hierarchy. There is evidence that Gombe females who acquire more meat in this way do have more surviving offspring than those who obtain less, suggesting one mechanism by which traits contributing to high social status are passed on. However, it is not necessarily nutritional benefits that make the difference in survival of hunters’ offspring. More likely, some of the same qualities that make

good hunters – and discriminating, adept social negotiators – probably contribute to a vigorous lineage for both parents.

Of course we should not expect the behavior of chimpanzees or any other species to replicate our own. What these observations do tell us is that the capacity to use food as a social tool is part of the ancestry we share with our ape relatives. In the chimpanzee case, this sort of behavior emerges when a strong social hierarchy exists. We can see something similar when we look at the variation in the social uses of food, whether as costly signaling or recruitment tool for political allies, in human societies.

SURPLUS, SHARING, AND HUMAN SOCIETIES

Abundance of food takes many forms, and plays numerous roles, in human societies; however, the options are much the same as they are throughout the animal kingdom. You can use it now, or later; and keep it for yourself, or share with others. For now we leave aside the deferred benefits of storage, which become relevant during times of hunger (Chapter 5), and focus on the social uses of food. It may seem cynical to consider generosity as a ploy for garnering influence and other benefits; however, this view is not inconsistent with acknowledging that people give to others without thought of reward. The empathy that motivates people to give is just as real as the desire to raise one's social standing; both are proximate, or immediate, causes of behavior. But in seeking ultimate (evolutionary) explanations for how people behave, researchers have found that hidden benefits often accrue to generosity, benefits that help to explain how and why this behavior remains central to the human adaptation. What is it about giving food away that makes it such a popular social activity? To find answers, we must look to the variety of circumstances under which sharing takes place. The intelligence that allows us to keep track of our relationships with others and our awareness of social status are standard elements of the human condition. However, it is the ability to manage generosity to benefit ourselves and our families in extraordinarily subtle ways that stands out among primates. The messages conveyed by human generosity are not only potent motivators of the actions of those with whom we interact socially; they have a specificity and flexibility that would not be possible without the ability to manipulate meaning as well as the physical world.

But how is it possible to tell that a venison steak is meaningful and not simply, well, a hunk of meat? This question presents a formidable challenge for the prehistorian, as we shall see. Until very recent times, cultural anthropologists have been able to observe patterns of food sharing in action and discuss their significance with people who make a living primarily by hunting and gathering.⁴ Although these groups live in varying environments, from desert to rainforest to arctic tundra, they seem to have in common a similar regard for meat as an especially desirable food. This attitude toward meat is most evident among populations that rely – as most do – primarily on plant foods for the bulk of their calorie intake. Not all animal foods are accorded the same status; grubs, insects, and fish, for example, do not garner the same attention as large game. People attend to food procured by hunting in a distinctive way that is not entirely accounted for by its nutrient content.

In fact, it is often the case that hunting is not particularly energy efficient. Although it is true that large game represent a high caloric payoff, the effort spent in the hunt is often high enough to make it a very costly activity when one accounts for the time and energy expended. Anthropologist Kristen Hawkes and her colleagues were able to demonstrate the energetic inefficiency of hunting among the Ache, a foraging group of the Paraguayan rain forest.⁵ By estimating the caloric return rates for common foods available to the Ache and their local abundance, they were able to predict an optimally efficient diet for their environment using the diet breadth model (Chapter 3). What they found was that Ache men could be more efficient by collecting certain plant foods than by pursuing game. For one thing, they gave away most of the meat they acquired; not even their families received an extra share. The question to be answered then became: Why do Ache men hunt at all?

What the Ache research team proposed was that hunting had benefits that were not accounted for by calculating the net capture of energy. Hawkes has hypothesized that hunting is, and was in the past, a kind of showing off – a demonstration of skill, fortitude, and overall health that communicated a man's worthiness as a mate. Not only were women impressed, but other men were more likely to accord respect to a successful hunter. Whereas status differences are weak among most hunter-gatherers, good hunters are more likely than nonhunters to garner high regard from their peers and have a high degree of influence on group decisions.

Subsequent analyses by Hawkes and other behavioral ecologists⁶ have provided support for the idea that in many hunter-gatherer societies, widespread sharing of meat by men rewards them with noneconomic benefits in the form of political influence, high status, and attractiveness to women. This conclusion has emerged from decades of testing various hypotheses to explain the way men share meat. There is little evidence to suggest that such generosity is reciprocated by the recipients; instead, meat is supplied to everyone regardless of their ability to return the favor or their past performance as providers. The widespread and indiscriminate nature of sharing also points away from any differential benefit to the hunter's blood relatives. Similar patterns have been found in a number of foraging societies, including the !Kung of southern Africa, the Hadza of Tanzania, and the Meriam of north coastal Australia.

The mechanism by which mens' generosity is translated into social and reproductive benefits often takes the form of costly signaling. The payoff is a simple function of the accurate information they provide in the form of an expensive and therefore reliable indicator of abilities that might make them valuable allies or mates. For their part, the recipients of the "I am a successful hunter" signal benefit from the accurate information they receive, which should help them to make advantageous decisions about whom to respect and with whom to form alliances. Surveys of opinions held about different hunters by their peers in hunter-gatherer societies indicate that successful hunters often do enjoy greater prestige than their less successful counterparts. There is also some evidence that women are influenced by hunting prowess in choosing men to father their children. Among the Meriam of northern Australia, well-attended funeral events are provisioned by sea turtle meat obtained with considerable effort from boats; in contrast, easy-to-collect meat from nesting turtles is not a popular funeral feast food. Men who provide turtles display their skill as hunters to a large audience that hums with gossip about who provided what quantity and quality of meat. So it is not just the meat, but the message, that drives the wide sharing of this highly valued food.⁷

Among foragers, the prestige that accrues to generosity with food fails to provide a basis for permanent, inherited, institutionalized differences in social status. At the end of the day, a good hunter who shares widely may be admired and respected; however, he lacks the power to coerce anyone. Few opportunities exist for anyone to stockpile valuables

when there is constant social pressure to share and little privacy. There are also practical reasons for keeping personal property to a minimum; high mobility encourages the habit of traveling light, and food storage may not be a worthwhile option.

THE USES OF ABUNDANCE

That these constraints were overcome in most parts of the world is clearly demonstrated by the archaeological record. Although the multitude of ancient hierarchical societies developed for varying reasons along distinctive pathways, competition between individuals and groups seems to be an element common to all. This social striving often took the form of public displays of generosity.⁸ The ability and willingness to share marks the giver's skills at acquiring and holding resources and also advertises the potential rewards of alliance with and deference to his wishes. Repeatedly being cast in the role of recipient of such generosity can erode status just as surely as hosting public events can enhance it. Some archaeologists argue that as this gap widens, implicit obligations are created that cannot be repaid materially by the less affluent, who offer their allegiance, labor, or deference instead. Successful candidates may end up administering the centralized collection and storage of grain and other resources to be distributed in times of hunger or used to support craft production and public works. In truly hierarchical societies, displays of abundant or special goods become reminders of differences in status and wealth. Among those goods are often to be found an array of highly valued and sometimes rare foodstuffs.

The use of lavish presentations of food and drink to enhance social status is a concept with which most people are familiar. Families strive to give their daughters the most elaborate weddings, and high society parties seek special foods (think caviar and champagne, the best wines, and elaborate presentations) and celebrity guests. Social competition is, of course, not limited to the well off, although the resources of the wealthy make for the most visible displays. Charity events sponsored by public figures are perhaps the closest in form and meaning to the competitive feasts in nonindustrialized societies; public giving of large amounts of money to some cause deemed worthy by the target audience both communicates information about the donor's generosity and wealth and challenges one's peers to give away even more.

Feasting as Competition and Display

Public consumption of food in quantity as part of a special occasion does not always leave a distinctive archaeological signature. Although clues exist in the form of special serving vessels, unusual foods, unusually large quantities of everyday foods, and public venues, they may not take us any further than the fact of a feast. It is generally much more difficult to determine what the feast was about, what it may have communicated, and what material functions it may have served. Ethnographers and ethnohistorians (who study contemporary cultures and historically documented ones, respectively), in contrast, have been able to generalize about types of public feasting and their functions. Their work provides the archaeologist with a framework for hypothesizing how and why similar events may have occurred in the distant past.

Some feasts are explicitly competitive; they are venues for one-upmanship – food fights of the social realm. Winners gain prestige and political support. This pattern is well documented historically and ethnographically, and it seems likely that competitive feasting played a similar role in past societies. Even communal feasts associated with rites of passage, like the tomb opening ceremonies of the Meriam, include a more subtle assessment of the quantity and quality of contributions made by the participants.

As social hierarchies become more stable, there is less opportunity for ambitious chieftains to compete for followers. Competition between people within the same social stratum remains common, but for those at the top, contests take place within a very limited circle of players. In this context, the function of feasting changes somewhat from competitive to diacritical – that is, the public consumption of food shifts from being part of an ongoing contest to taking the form of a display of superior wealth and power. Diacritical feasts, thus, mark the elite as special and remind the common folk of their subordinate role in society. The autocrat may not feel the need to court the masses; however, it does make sense to reinforce the status quo in a public setting by communicating the correctness and legitimacy of the social hierarchy.

However, if we want to document the distribution and display of food as social strategy, what should we look for? By their nature, feasts must be public; therefore, the food refuse, ritual paraphernalia, and containers for serving and consuming food and beverages will be found in public spaces such as temples, plazas, or monuments. These locations will accumulate quantities of bones, shells, or plant food remains that

exceed expectations for a single household. (This criterion alone is not sufficient to identify feasting, because a large and affluent household might produce similar remains in a domestic context.) Foods that are rare, exotic, or require a high input of labor to produce advertise wealth and act as a costly signal of the host's access to resources. The vessels used to cook and serve at feasts are sometimes of a distinctive style and form, or may be much larger than typical domestic pots. Sometimes they even yield residues that contain chemical signatures of their former contents. Often associated with food refuse suggestive of feasting are less perishable nonfood prestige items that are also put on display.⁹

Emerging Hierarchies: Feasts in Mississippian Society

Especially fertile ground for study of emerging hierarchies is found in eastern North America. Although the far-flung trade networks, maize agriculture, and flat-topped earthen mounds of the Mississippian tradition persisted for the 500 years or so between AD 1000 and the first European exploration, no single town or region emerged as a persistent center of political power. For this reason, archaeologists view the Mississippian political world not as a unified entity, but rather as a constantly shifting pattern of alliances and conflicts that allowed leaders to achieve temporary influence, only to yield after a short period to competitors.¹⁰ This situation seems ripe for interpretation as a case of competition between peers in which the public display and consumption of special foods might have played a prominent role. In fact, a number of archaeologists in the region have followed just this path, seeking evidence of competitive feasting. Whereas their findings confirm that public feasts took place in Mississippian population centers, their role in struggles for power and influence is still open to debate.

A case in point is an unusual deposit from Cahokia, the most populous prehistoric settlement in America north of Mexico. Cahokia, located in East St. Louis in the fertile bottomlands of the Mississippi River (Figure 2.1), is a complex of earthen mounds and associated living areas that reached its population peak around AD 1200. Cahokia lost a large portion of this population after a brief period of extensive regional influence, perhaps because of the effects of a long-lasting drought. During its emergence and development as a political player, however, Cahokia would have been a likely venue for competitive feasting. Evidence of feasting does indeed exist at Cahokia, most notably in an unusual set of deposits that underlie Mound 51 at the site.¹¹ These deposits represent

multiple episodes during which a pit was filled with a mixture of food remains and pottery and then subsequently covered and burned. The preservation of organic materials in this pit is exceptional for the humid temperate climate, in which items such as seeds and wood tend to deteriorate rapidly unless they are charred under just the right conditions. In the sub-mound “borrow pit” (so-called because it was a source of sediments used to construct earthen mounds), perishable plant tissues survived to yield a wealth of seeds, nuts, fruits, and wood fragments as well as abundant animal bones. These materials accumulated in the pit over a period of several years, while the main ceremonial part of the site was under construction.

The sub-Mound 51 pit contained food refuse different in a number of ways from the run-of-the-mill domestic debris usually associated with Mississippian houses. There was little sign of the patterns of bone breakage indicative of extraction of bone grease, suggesting a somewhat profligate approach to consumption. Such inefficiency and waste often characterize feasting and other forms of costly signaling. The deposit beneath Mound 51 was also rich in bones of swan and prairie chicken, both unusual occurrences at Mississippian sites (although the swans were likely not eaten, given the lack of evidence for butchering of the carcasses). Large river fish were also unusually abundant. Somewhat surprisingly, maize – the cereal staple of Mississippian diet – was relatively scarce, although native seed crops such as the sunflower were present in quantity. The unusual preservation of organic materials may be one of the reasons for the unusual composition of the assemblage. The pottery was not exceptional, except that many of the pots were larger than a single household would use. Together, all these elements make a strong case for Cahokian feasting repeated over a period of years, though whether competitive or communal in nature is unclear.

Other Mississippian sites with mounds have yielded similar evidence of feasting. One of these is the Lubbub Creek site in Alabama,¹² a single-mound center located 55 km west of Moundville, which was the regional seat of power. Although structures were not preserved from all of the mound’s four construction episodes, remnants from beneath the mound indicate that a succession of paired buildings were built and destroyed before the earthen mound was begun. The flat top of the mound was probably the site of communal activities and perhaps also the household of the chieftain and his family, based on historic records of mound use. Ceramic vessel fragments found atop the mound included a somewhat higher proportion of burnished treatment with a black film

on the outer surface than did assemblages from the village. This type of pottery was probably used for serving rather than cooking, but the difference is a minor one. More significant was the prevalence of large pots associated with the mound, in contrast to the wide range of vessel sizes in the rest of the village (intact vessels are rare, but vessel size can be estimated from the curvature of rims and vessel bodies). It seems that large groups assembled for meals atop the mound. Feasting on the mound also is supported by the unusual assemblage of animal bones found there, including a unique set of birds more likely to have been used for plumage than food – among them Carolina parakeet, cardinal, and bluejay, none of which were found in parts of the village outside the mound. This evidence, too, points to special occasions involving some amount of ritual and ceremony, rather than everyday activities.

There are also some striking differences in the way food was consumed both within Moundville itself and between Moundville and nearby contemporaneous sites. Mississippian settlements were of several types distinguished by the number of earthen mounds present, presence or absence of public architecture generally, population size and spatial extent, and other variables. Moundville itself, with its multiple mounds, numerous elite graves, and abundant exotic articles imported from all over North America, rose to become the most politically influential settlement in the region. A comparison of pottery assemblages from Moundville, a nearby single-mound site, and two small farmsteads shows that the Moundville elite did eat somewhat differently from their rural neighbors.¹³ Farmsteads had proportionally more maize cob fragments than high-status households at Moundville, which might indicate that Moundville residents were getting at least some of their maize as shelled kernels, removed from the cob and ready for grinding and cooking. This pattern is certainly consistent with collection of tribute in the form of food, which could then help to provision feasts or ride out periods of shortage. Feasting is suggested by the high ratio of serving ware to cookware in elite contexts at Moundville, paralleling the prevalence of large pots associated with the Lubbub mound.

It seems clear that a subset of people in Mississippian communities had privileged access to certain foods and other resources, and that they hosted public events featuring an abundance of food for all.¹⁴ However, the degree to which social hierarchies were institutionalized in Mississippian society is still debated by archaeologists. The deference shown to elite members of Mississippian communities captured the attention of European visitors to the Southeast who wrote about their travels;

on the other hand, movements toward political centralization and consolidation of power by a single ruler or regional authority appear to have lost momentum rapidly. Politics such as Cahokia and Moundville peaked in influence over a period of no more than a few centuries to be replaced by emerging powers elsewhere in the Mississippian culture area. However, in many parts of the world, social hierarchies became entrenched and status became a matter of heredity as much as (or even more than) individual accomplishments in statecraft or war. In these societies, feasting reached new levels of extravagance, luxury, and elite privilege.

Of Cabernet and Kings

Archaeological and documentary evidence converge in a particularly compelling way to document the complex social world inhabited by the people of Greece, Anatolia, and the Near East in the final two millennia BC. As states and empires rose and fell during this period, which spans the Bronze Age and the Iron Age, artisans produced enormous quantities of luxury items used to contain and serve food and drink at feasts. Both meat and wine were key ingredients of celebratory and commemorative meals. Vessels for serving wine or other fermented beverages are particularly informative because of their distinctive forms, frequent depictions of eating, drinking, and serving of food at feasts, and in some cases even their contents – residues that allow archaeological chemists to reconstruct ancient menus.

BRONZE AGE GREECE: FEASTING WITH THE WANAX. In archaic Greece, for example, the world of warrior-chieftains during the Bronze Age (2000 to 1200 BC) is well known both from investigation of Mycenaean palaces and the Homeric epics.¹⁵ The latter are perhaps best considered a kind of oral history in poetic form rather than as eyewitness accounts, having been written long after the events they recount. Still, the *Iliad* and the *Odyssey* capture elements of Bronze Age society that accord well with the archaeological evidence of life in the citadels of Pylos and Mycenae. At Pylos, for example, small chambers adjacent to the throne room contained large numbers of stemmed goblets made of clay, whereas the fragments of similar vessels from the throne room itself were made of metal. Archaeologist Martin Jones points out that the double-handled design of these vessels would have been ideal for

passing from hand to hand, as guests may have done at a feast similar to the one at Nestor's palace described by Homer in the *Odyssey*. At the site of the Pylos feast, as the quality of the wine vessels declined with distance from the palace and the king, or *wanax*, so presumably did the status of the attending guests. In addition to drink, guests consumed the meat of cattle and deer, whose bones were found in a number of discrete assemblages scattered across the site in a condition indicating that selected parts of each animal had been burned (probably as a sacrifice to the gods). Meat and wine were the product of the king's generosity; however, the storerooms of the palace and the inscribed tablets associated with them indicate that tribute flowed into the palace as well. Some of the goods thus obtained were used to support the elite lifestyle of the ruler's family; however, the king also had the important responsibility of holding in trust this surplus, which could be redistributed in times of famine.

A PHRYGIAN FUNERAL. Other notable examples of diacritical display of food in classical antiquity come not from the context of the feasts themselves, but from the disposition of food-related items in graves or tombs. Archaeologists have long relied on funerary assemblages to get a sense of the status differences within ancient societies, under the assumption that the dead retain the social position they had in life and are buried with items that affirm and symbolize that position. Often the most informative graves in an anthropological sense are those of high-status people, who were interred with luxury goods and prestige items reserved for the wealthy elite – including food or the vessels and other equipment with which it was served.

Perhaps the best documented example of a royal funeral in the ancient world comes from the site of Gordion in eastern Anatolia.¹⁶ Gordion was once the capital of Phrygia, ruled by King Midas of Greek legend (known as Mita to the Assyrians). A great earthen mound at Gordion was found to contain a deeply buried wooden tomb. The remains sealed within it included exceptionally well preserved organic items, such as dyed textiles and wooden furniture. Also interred with the body were approximately 157 bronze vessels, some of which contained residue. Using a battery of analytic techniques, archaeologist Patrick McGovern of the Museum Applied Science Center for Archaeology at the University of Pennsylvania was able to isolate and identify "fingerprint" compounds characteristic of different foods and beverages. Wine was

indicated by the presence of tartaric acid and calcium tartrate; barley beer by calcium oxalate; and honey mead by traces of beeswax. Most likely the liquid in the vessels was a kind of grog, a combination of all three fermented beverages.¹⁷ Along with the grog, guests at the funeral feast dined on lamb (or mutton or goat, as indicated by fats characteristic of goats and sheep) as well as a high-protein legume. The combination of compounds recovered from the vessels, along with the absence of bones, suggests a meal along the lines of a barbecued lamb and lentil stew flavored with anise and perhaps fenugreek and bitter vetch.

The meal from the Midas tomb has many parallels with the feasts of the Mycenaean Greeks of the Peloponnese celebrated some 500 years previously. The guests in both cases dined on sheep or goat meat and ample quantities of a fermented beverage. In both, people of high rank were distinguished by elaborate service ware and other luxury items. However, in the case of the Midas tomb, the guest of honor was sent to his grave with the leftovers.

Food of the Gods

In the New World, elites also distinguished themselves by appropriating distinctive styles of eating and drinking in death as well as in life. For the Maya nobility, high status was often expressed by the consumption of a particular luxury food: cacao.¹⁸ The cacao beverage served among the Maya was not usually sweet like modern chocolate, though both are derived from the fruits of the cacao tree, *Theobroma cacao*. The Maya mixed the extract from fermented and roasted cacao seeds with water and seasonings (such as chili) and whipped the resulting beverage to create a frothy head. Most of the evidence for cacao consumption comes from depictions of scenes involving nobles and deities on pottery vessels recovered from elite residences and tombs. Traces of theobromine and caffeine, both alkaloids found in cacao, have been recovered from Maya funerary vessels interred in an elite tomb at Rio Azul, a Maya center in Guatemala. Some of these vessels are of a particular cylindrical form used to contain and prepare the cacao beverage, as seen in a depiction of a woman pouring cacao from one vessel into another to create the frothy head that was desirable as a sign of quality. Although cacao was apparently not exclusively for elite use,¹⁹ it was highly esteemed as the “food of the gods” and thus reserved for ceremonial occasions and closely associated with the activities of kings, nobles, and deities.

The Wages of Wealth: Storage and Redistribution

The material and social affluence displayed by Mississippian chieftains and Mycenaean kings was not purely an advertisement of living large or a way to snub subordinates. Public generosity had costs as well as rewards. These costs were incurred materially when entrepreneurs transformed surplus into party food and expensive gifts to potential allies. However, the storerooms at Pylos and many other seats of power also show that some of that surplus was offered up in the form of tribute by members of the community at large. Perhaps this practice was at its inception a form of competition between equals, but was transformed into an obligation on the part of those whose generosity consistently fell short of their peers'. Rather than compete with their social superiors, they offered modest portions of their own surplus produce to the larger events staged by more powerful figures. Part of the tribute was skimmed off by the elite to support their extravagant lifestyle, but part also went to serve more public purposes – to support craft specialists whose goods brought in revenue through trade and, perhaps most important, to fill granaries with emergency rations. Such facilities – aboveground corn cribs for the Mississippians, rooms packed with wine, olive oil, and grain in Mycenaean palaces – are consistent features of every ancient city and of many smaller settlements as well throughout the ancient world.

The Inca empire of Andean South America is particularly well known for its ability to mobilize tribute in order to serve the state.²⁰ Late in prehistory, the Incan state emerged in the highlands around Cuzco, Peru, shortly before the arrival of Europeans on the shores of the New World and rapidly set about expanding its territory. During its relatively brief history, which was truncated by Spanish conquest, the Incan empire established an efficient bureaucracy capable of controlling a vast geographical area. Tribute from the hinterlands was used to fuel such public works as the construction of roads, temples, and fortifications and to support weavers and other skilled artisans. Effective collection and management of tribute from the empire was crucial to its continued existence, and the Incan method of conquest ensured the flow of goods into the capital by providing people with liquid motivation in the form of beer. Maize beer, called *chicha*, was distributed to work parties on public projects along with food. This practice is especially well documented at Incan provincial sites, where production and consumption of *chicha* had an important role to play in supporting peaceful acquiescence to Incan

rule. Beer drinking by elite and commoners alike inspired the creation of enormous quantities of distinctive ceramic vessels used to produce and store *chicha*. These items are more abundant at provincial sites than they are in the core of the empire. Conquered provinces were also put to work producing maize, much of which must have gone into the Incan central storehouses.

ABUNDANCE, DIET, AND HEALTH: THE EFFECTS OF SOCIAL INEQUALITY

The *chicha* example is a reminder that allocation of food surplus within a socially stratified society is not purely symbolic but has direct material consequences for consumers, especially those for whom luxury foods and even nutritional adequacy are out of reach. Abundance enjoyed by the haves does not always trickle down to the have-nots. In the case of luxury foods, privilege is a matter of being able to enjoy delicacies, to indulge refined palates, and impress one's peers with the trappings of affluence and rank. Whereas these benefits are mere embellishments for the well-fed, the nutritional deficits experienced by the poor extract heavy costs that are paid in the currency of delayed and stunted growth, skeletal pathologies, susceptibility to disease, and inability to work. Few escape these negative impacts when they arise in the context of a major subsistence transition, such as the reliance on cereal grains brought about by the transition to farming. However, the less privileged segments of society suffer disproportionately from populationwide deficiencies, famines, and shortages, whereas the health of the elite tends to be buffered somewhat by access to a wider variety of foods, including meat and other protein sources. The upper crust also has a more direct route to the sources of power that control surplus food and its distribution to the populace at large during times of crisis.

A monotonous diet is unlikely to provide adequate nutrition, unless it is carefully designed and administered. The health risks of eating only a few types of food are particularly high when cereal grains provide the bulk of calories, as it did for the early maize farmers discussed in Chapter 4. In the case of maize, iron deficiency anemia and associated bone pathologies are the result. For this reason, archaeologists are often interested in comparing the dietary diversity of low- and high-status people who lived in the same community or region. Generally they expect that the positive correlation between diversity and health will hold up, simply because higher status people have better access to a

variety of foods. However, in some cases the reverse seems to hold, as when rural farmers take advantage of the countryside for greens, game, and other uncultivated foods that provide important nutrients. Thus, the same wild foods that earn the scorn of the urban elite may serve to enhance, not degrade, the health status of the less affluent.

To find out whether status and nutritional adequacy are correlated, archaeologists need to look at domestic contexts rather than the more public settings characteristic of feasting and funeral ceremonies. Animal bones from refuse deposits provide most of our information about everyday meals, simply because they are more likely than plant materials to be preserved and recovered in the course of excavation. Collections that have been examined in order to check for variation in dietary diversity within a community or local group usually show that people living in elite households prepared (or were served) and ate a wider variety of foods than their less affluent counterparts.

The maize-dependent cultures of the Americas make a particularly valuable test case for understanding the effects of status on diet and health because of the poor nutritional quality of the staple food and the ability to measure its consumption by analyzing bone chemistry (see Chapter 4). In Mississippian households situated atop earthen mounds, meat was plentiful, judging by the high frequency of discarded bones from choice, meaty parts of the skeletons of deer and turkey.²¹ The Mississippian elite also had access to a variety of animal foods seldom found in commoner households, many of which probably had symbolic significance as well as nutritional value – black bear, cougar, fox, scarlet ibis, and numerous songbirds fall into this category. Rare or exotic species were also enjoyed by elite families, such as bison from the Plains, and shark from the Atlantic or Gulf coasts. At one Arkansas site, the now-extinct passenger pigeon was a delicacy whose bones are found primarily in a single house occupied by a high-ranking family.

Did the variety of foods enjoyed by elite consumers really benefit their health? For the Mississippians, there is little evidence that people of low rank suffered a higher incidence of nutritional pathologies than their high-ranking neighbors. Such differences do seem to have characterized Maya society, in which the social hierarchy was more clearly delineated than it was among Mississippian groups. Like the Mississippian elites, high-ranking families among the Maya enjoyed a relatively diverse diet that included meat from a variety of sources. Skeletons from elite Mayan tombs are sometimes taller on average than their commoner counterparts, suggesting better nutrition during childhood. Lower class

Mayans also had a higher incidence of enamel defects that indicate interruptions in the growth of teeth. Some, although not all, studies of Maya skeletons also show that high maize consumption and low dietary diversity characterized the lower sectors of the social hierarchy. A frequent result was worse dental health among commoners, whose high-carbohydrate diet encouraged tooth decay; however, sometimes the benefits of dietary diversity were countered by the highly refined maize products consumed by the elite, such as *atole* (finely ground maize flour mixed with water). Such foods tend to stick to the teeth and provide ample surface area for bacteria to feed on. Similar patterns of high caries rates among the elite have also been found in Japan and dynastic Egypt.²²

BEYOND STORAGE AND SHARING: SURPLUS AS SYMBOL

It should be clear by now that human methods of putting surplus food to good use far exceed those of other animal species, at least in terms of variety and originality. Storage and sharing with conspecifics are two such methods that have material benefits whose contribution to survival and reproductive success can be estimated in a relatively straightforward fashion. Storage shifts surplus to times of need, becoming one of the strategies used to buffer seasonal and periodic shortages. Sharing with relatives is an indirect way of ensuring that one's own genes are passed on. Even sharing with unrelated individuals makes good economic sense if it involves a resource that would not be worthwhile to defend, such as an animal carcass that will decompose if not eaten right away. Storage, sharing food with kin, and tolerated theft are not distinctively human, although sharing in general is a much more prominent feature of social life than it is in most other animal species. Humans have the potential to expand the function of surplus food (or rare, exotic, or highly valued foods) into the realm of meaning. Sponsoring a lavish feast can be a form of costly signaling that garners prestige and attention instead of material goods. Such a display of generosity is costly, ensuring that only affluent individuals (who have entrepreneurial skills or leadership abilities) can manage it, thereby keeping the message an honest one. Recipients of food thus shared acquire not only the resource, but useful information about prospective leaders.

There is no pat way to connect the information given and received in costly signaling to reproductive success and ordinary Darwinian fitness, although such a connection could certainly be envisioned. However,

we do know from studying contemporary human societies that public generosity with food, particularly if it is difficult or expensive to obtain, is one way for a person to acquire respect and prestige. Although this regard may benefit one's children, it may also cause the practice of costly signaling to spread through imitation by other aspiring status-seekers – a cultural form of transmission that can operate at speeds only dreamed of by the human genome.

Social dominance, which plays a role in access to food in many primate societies, is also a feature of human life. However, in the human case, dominance has nuances of meaning that go well beyond the temporary triumph of securing the biggest drumstick or chasing the competition away from a patch of ripe fruit. Princes, nobles, priests, and other dignitaries do not simply enjoy their privileged access to more or better foodstuffs than those low on the social pyramid. They advertise it, reinforce it, and symbolize it through lavish public displays. These may take place at feasts or at other ceremonies such as public celebrations and funerals of high-ranking people. In these cases, consumption of luxury foods or simply enormous quantities of everyday food prepared in elaborate ways is the privilege of the rich and famous. Common folk may be allowed to peer into the dining hall or observe from a distance while enjoying their own festive (but much less expensive) meals. No doubt elite diners hope that their extravagance will awe the observers and reinforce their regard for their social superiors, and perhaps it does – at least until the gap between rich and poor widens so far that it begins to swallow up the disenfranchised while the wealthy dine on delicacies. Just ask Marie Antoinette.

Luxury foods may be inconsequential for nutrition and health, particularly if they are rare, consumed in small quantities, and are more important as status objects than as food (consider caviar, which is universally acknowledged to indicate luxury dining, although it appears on very few Americans' top ten favorite foods list). However, people of high status also frequently have better access to a wide variety of foods. Multiple food sources are more likely to provide adequate nutrition than a homogeneous diet, particularly one that is dominated by carbohydrates and low in protein. In highly stratified societies, it is common to find that the refuse of high-status households contains bones of more different species than do similar deposits associated with low-status families. Dietary variety also means more meat and more protein, so in general, the elites within ranked societies suffered less from iron-deficiency anemia and associated ailments than commoners

did. In New World populations, the impact of protein deprivation is often seen in elevated levels of the isotope ^{13}C in bone apatite, which shows that maize was a major source of dietary protein.

The social hierarchies in which food played such an important role as a marker of status differences were inevitably accompanied by some degree of centralization of government and expansion economic systems to include trade over long distances. With states and empires came conquest and the transmission (sometimes the imposition) of cultural traditions into populations with little experience of the wider world. However, the exchange of domesticates, recipes, and processed foods began long before expanding civilizations began to stir the melting pot of food traditions we see today. The first wave of expansion of an established food tradition came with the farming populations who moved from the Near East into southeastern Europe, eventually to spread throughout the continent. Similar waves of agricultural colonization fanned out from other hearths in eastern Asia and the Americas as food production began to replace food gathering as the dominant way of making a living over most of the globe. The processes that drove this expansion varied: movements of plants and animals, information, and people were all involved. After agriculture and animal herding became widely established, some of the complex societies they supported tried their hand at expanding by scooping up more territory, creating rich opportunities for the exchange of foods and food technologies across cultural boundaries. The Roman empire created just such a situation, and the expansion of European powers into the New World brought the clash and combination of food cultures to new levels of innovation. The spread of foods and cuisines into new cultural settings and its consequences are the subject of Chapter 7.

7

CONTACTS

Foreigners cannot enjoy our food, I suppose, any more than we can enjoy theirs. It is not strange; for tastes are made, not born. I might glorify my bill of fare until I was tired; but after all, the Scotchman would shake his head and say, "Where's your haggis?" and the Fijian would sigh and say, "Where's your missionary?"

Mark Twain, *Roughing It*

The display of fancy foods to enhance prestige often gets a boost from the importation of exotic goods which, because they are rare and often expensive, make ideal costly signals of wealth, power, and entrepreneurial skills. However, foods introduced through cultural contacts can have much more far-reaching consequences, becoming staples and sometimes completely replacing traditional sources of calories. When confronted with a novel food, people exhibit a wide range of responses at both the community and individual levels, from revulsion and rejection to enthusiastic incorporation into existing food traditions. Where on this scale any particular instance of food introduction falls depends on a number of factors. Historical happenstance often accounts for the availability of new foods – the where, when, and how of introduction. But to understand why some are adopted and others ignored, we need to consider both influences on human decision making and the forces of culture, which sometimes resists novelty but also plays the important role of incorporating new foods and techniques into the body of knowledge passed on to younger generations. When it comes to food, this stabilizing influence of traditional knowledge supports food systems that have worked reasonably well in the past, while allowing new information to be assimilated.

ACCEPTANCE AND DISPERSAL OF NOVEL FOODS

The great range of food options we enjoy as humans coupled with the accumulation of food knowledge and practices across generations creates a unique approach to novel foods. Although animals tend to exhibit caution in sampling unfamiliar foods except under unusual circumstances (such as extreme deprivation), in experimental settings some mammals (rats, for instance) explore these novel items, or at least attend to them. Juvenile rats have been observed seeming to mimic the feeding behavior of older and more experienced individuals, in some cases smelling their breath for cues.¹ There is some evidence that carnivore mothers “teach” their young how to handle prey (there is controversy about whether true teaching is going on in this case or a more general facilitating of innate drives, but in either case the point holds that mammals learn what and how to eat). In humans, imitation and learning play a much more important role in the development of food-related skills and preferences. We learn from our elders (and peers) not just what and how to eat, but what constitutes a proper meal, what foods are forbidden by custom or belief, healing properties of foods, and many other details that form complex food traditions.

Another distinctively human aspect of food choice is the frequent introduction of novel foods through trade and other social interactions between populations far separated in space. Long distance travel brings into contact people with very different dietary habits, and the human facility for the transmission of information through language makes for a potentially very rapid spread of new foods and associated technologies. But even though food fads can spread like wildfire, and for a variety of reasons having nothing to do with nutritional benefit or Darwinian fitness, people can also be very resistant to such novelties even if they appear to have practical benefits. Suspicion of novelty may seem irrational and interfere with well-meaning efforts on the part of nutritionists and agronomists to improve diets and agricultural productivity; however, being cautious also guards against the risk entailed by surrendering familiar practices with well understood outcomes in favor of new and unknown crops and technologies. Such caution is especially valuable when the introduction of new foods is uncontrolled and unsupervised by experts, who at least have a body of relevant knowledge and perhaps can even offer support during the period of transition. When exotic fruits, grains, and animals are flowing into a population’s reach as a result of vigorous, profit-motivated trade or the arrival of strange

new neighbors with unfamiliar foodways, the risks of hasty adoption are higher, and caution is warranted.

There is apparently no general rule to invoke that might allow us to predict whether, in a particular situation, a new food will be accepted, ignored, or actively rejected. However, by exploring several examples, it is possible to identify some of the variables that seem to make a difference. An obvious candidate is economic advantage (or disadvantage), which can be analyzed using tools of behavioral ecology that estimate the effects a new food might have on overall energetic efficiency. Risk and uncertainty are also factors to consider – people may not be willing to abandon a system that provides energy reliably for one that might vary greatly in outcome even though maximum possible profits are higher than what they can achieve using traditional methods. But if acquiring a new exotic foodstuff is simply a matter of paying a one-time price, rather than investing in an entirely new way of making a living, other motivations come into play. Luxury foods are often exotics that stamp the possessor as influential, wealthy, and plugged in to the world of commerce. The pursuit of status objects in imitation of the rich and famous can further the spread of new food customs until they become commonplace. As prestige symbols, exotic foods need not be nutritious or even tasty, just difficult or costly to obtain and therefore rare.

To sample the diversity of responses to novel foods, consider the following three examples.

1. Maize, the major food staple of New World farmers at the time of European contact, played a minor role in human diets in eastern North America for nearly a millennium following its initial introduction from Mexico. The appearance of maize in the East by 200 BC² is unaccompanied by other signs of contact with the people who lived in the Mexican source area. Maize kernels may have been acquired indirectly through trade rather than through direct contact with maize growing societies; however, maize does not travel well without human companionship because it lacks the ability to disperse its own seeds. It was only after AD 900 to 1000 that maize rapidly rose to become the staple crop of the region, eventually replacing most of the indigenous seed crops such as goosefoot. The abundant remains of cobs and kernels that signal this change in agricultural production are accompanied by a sharp upswing in the carbon isotope ¹³C in human bone,

indicating that people were consuming maize in quantity (see Chapter 4). Maize, then, was incorporated into human diets at first on a very limited basis, for reasons that are not well understood. It may have been poorly adapted to the regional climate, relatively unproductive, or initially a prestige food not intended for mass consumption.³

2. The tomato, *Lycopersicon esculentum*, originated in the Andean region of South America, although it developed a secondary center of diversity in Mexico. Initially, Europeans regarded it with suspicion because it was closely related to a group of plants we now know as the Solanaceae, or nightshade family, which includes a number of plants traditionally associated in folklore with witchcraft. These plants, which include henbane (*Hyoscyamus niger*), belladonna (*Atropa belladonna*), and deadly nightshade (*Solanum nigrum*), contain powerful alkaloids that cause hallucinations, a sensation of flying, and numerous other (and much less pleasant) psychotropic effects. Thus, it is not surprising that Europeans were wary of consuming this “wolf peach” (the English translation of the Latin genus name). However, the tomato was eventually to become a major component of many European and Asian cuisines. Italian food without tomato sauce is difficult for many contemporary diners to imagine. In this case, a powerful aversion based on folk belief was replaced by acceptance and eventual integration into the recipient cultures’ food traditions – even to the point of becoming an indispensable ingredient.⁴
3. Finally, there is the matter of dogs as food. Contemporary Americans are most familiar with their use as a meat in East Asian cuisines, but dogs have been eaten at one time or another in most world regions. Their bones are frequently found in contexts indicating that they were butchered and consumed along with other food animals. In Mesoamerica, fat little dogs were specially bred to provide meat. To be sure, their dietary role is only one aspect of dogs’ multifaceted and complex relationship with the human species. However, for most contemporary Americans and Europeans, the idea of eating a dog is abhorrent. They are companions and work colleagues, even servants, but never food; their relationship with humans in these cultures is so intimate and social that to eat them seems almost cannibalistic.

These cases illustrate that the fate of novel foods is tied to a complex mix of decision criteria and means of dispersal. Economic considerations are often important, but not always primary; they can be nudged aside by the weight of cultural tradition, symbolic associations, and historical happenstance. Any or all of these possible influences may come into play in a given case. However, I believe that our best chance at understanding the “why” of food introductions is to consider them in light of the opposing and balancing forces of inheritance and innovation. As humans, we are omnivores; as intelligent mammals, we tend to be exploratory. However, this exploratory behavior is balanced by a measure of caution; individuals who tried everything indiscriminately were probably not treated kindly by natural selection. As cultural beings, we have notions of what is and is not proper food that we have assimilated via social learning, as well as a facility for absorbing information from a wide variety of sources.

THE SPREAD OF AGRICULTURE IN PREHISTORIC EUROPE

The case of the introduction and spread of agricultural systems from the Near East across the European continent is one that pulls into sharp focus the question of how contacts between different groups of people result in far-reaching changes in diet and subsistence. What is it exactly that spreads from a place of origin – crops and livestock, people, technological information, or all three? Did farmers and their domesticates displace hunter-gatherers, or instead convert them to the agricultural way of life through intermarriage or conquest? The answer is: yes. Various combinations of material exchange, sharing of information, and movement of human populations have to be invoked to account for the geographical distribution of farming communities that we see today. Each has its own story to tell.

This topic has attracted much scientific attention to the problem of distinguishing between scenarios that explain the shift to agriculture as a population replacement event as opposed to a flow of goods and information across a frontier. In plainer terms, did Near Eastern farmers colonize southeastern Europe first, budding off new communities that eventually spread across the European continent? Or did they pass on knowledge and domesticates to indigenous Europeans, initiating a chain of exchanges that culminated in the nearly complete conversion of the continent to farming and herding?

One of the earliest systematic tests of these alternatives was carried out by Ammerman and Cavalli-Sforza,⁵ who mapped radiocarbon dates for the first appearance of agriculture across Europe. Their data were the seeds and bones of domesticates and distinctive artifact types known to be associated with farmers. What they found was a temporal cline from southeast to northwest – the first appearance dates for agriculture were earliest in Greece and the Balkans, close to the Near East area of origin, and latest in the British Isles. The relationship between date and distance was consistent, suggesting a concentric wavelike pattern, as if farming technology were a pebble dropped in a pond somewhere in Anatolia, with the outer rings taking longer to appear than the inner ones. This spread from a center suggested a movement of people who carried with them a full set of traits that left a distinctive signature of the Neolithic cultural period. In the central European plain, this pattern had long been known as the Linearbandkeramik, or LBK, culture – defined by its domesticates, decorated pottery, rectangular longhouses, and a tendency to settle on the rich and easily tilled soils of river valleys.

LBK settlements are easily recognized by their consistent archaeological signature, which contrasts with the hunter–gatherer sites that preceded and, in some cases, coexisted with them in the region. However, precisely what happened during the brief span of LBK and after to further the spread of agriculture is less clear. A recent analysis of radiocarbon dates has shown that agricultural communities appeared rather suddenly in some parts of Europe, such as the LBK region (suggesting in-migration), and became established more gradually in peripheral areas, such as Britain (consistent with adoption by local people as the primary means of dispersal).⁶ Ethnographically, contacts between foraging and farming groups often develop into well-established conduits for exchange of goods that would be unavailable otherwise – grain for animal hides, for example. Friendly relations can result in marriages that connect the two groups in a network of kin, often with a bias in favor of women marrying into the more socially and politically dominant group (usually the farmers or herders that have wandered into or colonized hunter–gatherer lands). These women would have adapted to their new homes by learning how to produce food and provide for their families in the customary way, by cultivating crops or preparing food from domestic animals.

These ethnographic examples can give us an idea of how things might have worked in the spread of agriculture, but finding evidence of the processes involved is a challenge, to say the least. So what do we

have? A relatively new source of data comes from DNA and its protein products, such as enzymes. The composition of the human genome can be used to trace the history of populations, using methods similar to the ones that are so helpful in constructing phylogenetic trees (Chapter 1). Like species, human populations tend to diversify as they become separated from each other and form relatively isolated gene pools. Genetic distance – measured by looking at frequencies of different alternative genes, or alleles, or the proteins they yield – can be indicative of how long lineages have been evolving on separate trajectories. Of course, the picture thus developed is confounded by the exchange of genes between populations in recent times, as barriers to travel have diminished and people are more likely to choose partners from outside of their own ethnic group or ancestral population.⁷ This effect makes it more difficult to track population histories, although we can still obtain useful information by looking at the genetic profiles of modern populations.

For scientists interested in the spread of agriculture in Europe, such molecular studies are aimed at determining how much of the modern European population can be traced back to the Near Eastern homeland of crops such as wheat, barley, cattle, and sheep. The results are easier to interpret when they are drawn from a part of the genome that is transmitted only in one sex, so that genetic recombination does not make the line of descent difficult to follow. Mitochondrial DNA (mtDNA), found only in cellular organelles called the mitochondria, is passed from mother to child, so that it travels from female to female. The Y chromosome instead is found only in males, following a line of descent from father to son. Both of these portions of the genome have rapid rates of mutation, so there is plenty of change even over short periods of time. Both have been targeted to identify genes in modern Europeans that may have come from Near Eastern farmers who migrated into the region many millennia ago.

Findings to date are difficult to summarize because data from protein products, mtDNA, and Y chromosome DNA are not perfectly congruent and are open enough to interpretation to support some disagreement even among experts. However, all data so far analyzed indicates a relatively small admixture of genes of Near Eastern origin among modern Europeans, between about 12 and 25 percent, being somewhat higher in the male lineage, represented by the Y chromosome.⁸ It has been suggested that males were more likely than females to intermarry with local hunter-gatherers,⁹ which is consistent with the most common ethnographic situations. So although some mixing of populations occurred,

which no doubt facilitated the flow of information about farming, most of modern Europe's gene pool can be traced back to earlier hunter-gatherers who had occupied the continent since the Pleistocene. There must have been a great deal of technology transfer going on independently of intermarriage, perhaps through the exchange of gifts and commodities. Hunter-gatherers either became farmers or retreated to habitats unsuited to cultivation.

Analysis of human skeletal remains adds some interesting twists to the history reconstructed from DNA. Metric data from human skeletons suggests that the original Near Eastern population was much more diverse morphologically (and presumably genetically as well) than the subpopulation that colonized southeastern Europe. Farming groups squeezed through this genetic bottleneck in Anatolia, resulting in a colonizing population of comparatively low diversity. Their skeletal traits indicate that these first colonists stood out among the hunter-gatherers of southeastern Europe; however, their distinctiveness became blurred as agriculture made its way north and west. Here, there was relatively more mixing and local adoption and less in-migration.¹⁰ Even in the LBK region of central Europe, there is evidence from strontium isotopes in bone that people who foraged in the uplands (relatively high ratios of ^{87}Sr to ^{86}Sr) were buried in LBK cemeteries in river valleys (where environmental levels of ^{87}Sr are much lower).¹¹ The proportion of studied female skeletons that represent uplanders is higher than that of males, suggesting that it was common for forager women to join LBK communities. For the most part, they were buried somewhat differently as well, for example, often lacking the characteristic style of adze (a woodworking tool) found in LBK graves.

Early colonists from Anatolia became established in the Balkans, from which they spread into central Europe as the LBK people. They probably had larger families than their less settled neighbors, and their numbers grew. The newcomers thus displaced some of the local foragers, but they also absorbed others into their communities, thereby losing their initially distinctive cultural character and creating new kinds of societies. By the time agriculture arrived in western and northern Europe, it was mostly local foragers who made the switch from reliance on game and wild plants to a more settled existence in farming villages.

The economic logic of subsistence intensification (see Chapter 3) and the pursuit of food security (Chapter 4) probably account for many of the individual decisions made to take up crop cultivation and animal husbandry. However, there is also the tendency of farmer populations to

grow at a higher rate than most foragers. Thus, novice farmers, assuming that they were successful, would have passed the torch to their own numerous children, who were fruitful and multiplied, and so on. It is easy to see how this process would cause an increase in the number of farmers in a region simply as a function of relatively uncomplicated cultural transmission from older to younger generations. Agricultural communities would continue to proliferate even if a few rebel offspring reverted to the old ways. As human populations grew, the possibility of making a living without food production became increasingly remote.

EATING, DRINKING, AND ROMAN EXPANSION

Whereas the practice of agriculture spread across Europe through relatively informal types of exchange, intermarriage, and the high reproductive rate of farmers, later introductions of foods and food customs were often tied to the exploration and sometimes conquest of new lands by ancient states and empires. One such period of expansion is the Iron Age of central and western Europe (which lasted from 700 BC to the departure of the Romans, a date that varies across the continent but in no case is later than AD 500). The Mediterranean world began to explore the vast European interior as a profitable source of trade wealth. Indigenous farmers and pastoralists were able to offer raw materials that were rapidly being depleted by the activities of intensive agriculture and urbanization, such as forest products and raw metal ores. What they wanted in return were luxury goods, including wine and drinking vessels, which became tools in the political and social maneuvers of developing chiefdoms. In the later Iron Age, the expansion of the Roman state accounts for many of the food introductions that were to become standard components of later Medieval European cuisine. The long distances that separated the Roman core in Italy from much of the empire, including temperate Europe, meant that Roman expansion was a potent conduit for the travel of foodstuffs far from their region of origin. The result was the introduction of many Mediterranean plants into regions where they were not native; some never became established locally, whereas others were able to adapt well enough to be incorporated into gardens, remaining long after the Romans themselves had left.

The custom of drinking fermented beverages on special occasions such as feasts, and the role of special drinking equipment in the social display of status, were discussed in Chapter 6. Whereas wine was preferred in much of the Mediterranean, and Phrygian grog had its

adherents, in temperate Europe the native brew was most likely a kind of barley beer or perhaps mead (brewed from honey).¹² Modes of presenting and drinking these beverages changed as metals became widely available throughout the interior of Europe during the Bronze Age (from about 2000 to 700 BC). Bronze drinking vessels came to replace the special ceramic cups that accompanied high-ranking people of earlier times and were interred along with whole wagons and great quantities of gold and bronze ornaments.

These traditional drinks and vessels were supplemented and, in some cases, supplanted as elements of Mediterranean wine culture became more widely available during the Early Iron Age. The Greek trade outpost of Massalia (now Marseilles), founded around 600 BC, became the major supplier of wine to southern France and of less perishable trade goods, such as ceramics and metals, into the interior. Over the next few centuries, much Massalian wine – traced largely in the form of the distinctive amphorae in which it was transported – made its way into what is now France. However, wine was not an instant hit across the European continent, in part because of the challenge of transporting it overland for long distances and delivering it in drinkable condition. Thus, in central Europe wine remained comparatively rare during the Roman era.

The problem of perishability did not, however, preclude the importation of wine drinking equipment into lands distant from wine-growing areas. This is exactly what happened in the Hallstatt region of central Europe, where wine vessels of elaborate manufacture played a restricted role as status objects, often ending up in elite graves. A funerary assemblage that illustrates this way of using imported drinking vessels is associated with a young woman buried at Vix in Burgundy.¹³ She was interred under an earthen mound along with numerous items of great value, among them a bronze krater – a giant wine-mixing vessel of Greek manufacture standing 1.6 meters in height (a little more than five feet). This item was not imported as a wine container, for wine was too perishable to travel such a distance and remain drinkable. In fact, it was probably packed in pieces for ease of transport and then assembled on arrival. The audience for this display was probably, in keeping with regional tradition, gathered for a funeral feast. The Vix krater is an especially dramatic example of an object associated with exotic food customs being appropriated as a symbol of social rank, but unaccompanied by the flood of novel foodstuffs that so often characterize cultural encounters.

In parts of Europe distant from Massalia and other trade outposts, the initial impact of Mediterranean food traditions seems to have been limited to the substitution of metal wine vessels for more traditional containers. These novel items were rare enough to be available only to the few, making them ideal for displaying status. However, the spread of exotic foodstuffs was hampered by the rigors of travel into the European interior, which was time-consuming enough to push the limits of then-current food preservation technology. Furthermore, the plants themselves were often poorly adapted to survive in the North. The situation was to change over the next several hundred years, as Rome grew to become a regional power and began a phase of colonial expansion. Strangers appeared in northern Europe, equipped with their own familiar foods to help them establish new homes in the provinces. Many of the foods that traveled with the Roman frontier stayed, even after the Romans themselves had retreated.

During the first century AD, the Roman state entered a period of expansion that eventually resulted in the establishment of colonies or military outposts across much of Europe, including parts of what is now southern England and Germany. The empire, thus, came to encompass a wide variety of landscapes, from the semi-arid scrub of the circum-Mediterranean to the chilly and forested north. Food resources from these diverse zones traveled along Roman roads, expanding from the thin trickle of goods – mostly associated with alcoholic beverages – of earlier times to a much broader flow that carried condiments, fruits, and garden vegetables even to the farthest reaches of the empire.

We do have documents that tell us something about how households were provisioned along the frontier and in the colonies and what goods were commonly traded. However, the archaeobotanical record can answer questions that historical documents cannot: Preserved seeds, fruits, and wood from ancient settlements include not just the species considered worthy of note by chroniclers of the time, but the refuse of daily cooking and eating preserved by carbonization or waterlogging. This rich data base tracks the initial introduction of exotic plants, mostly from the Mediterranean region, and provides a record of which species were adopted and grown locally and which remained luxury goods that largely disappeared along with Roman infrastructure.¹⁴ Early appearances of exotic plants including fruits (such as dates, olives, figs, and peaches) and condiments (including summer savory, celery, and coriander) are mostly associated with Roman military posts, or civil sites with a Roman military presence. Foods familiar from home apparently were

preferred, and cooks replicated Roman cuisine as closely as possible under “field” conditions. The more common imported plant foods, such as peach, pear, apple, and the wine grape, quickly made the transition to domestic civilian contexts, probably because they could be grown locally, whereas rare items (pomegranate, for example) remain closely associated with the military. By the final phase of the Roman occupation, AD 250 to 400, relatively few sites had the rare imports, and these are found in the southern part of the empire, suggesting retraction of the communication routes that supplied the frontier with food. In contrast, plants that could be grown locally had become widespread and were firmly established in regional European cuisines.

In this case, it seems that all or most of the new food plants that adapted well to local conditions were added to the existing repertoire of traditional foods. Most of these imports were either fleshy fruits, nuts, or condiments rather than staple crops. Barley and wheat were already well established locally, having arrived in the first wave of Neolithic expansion. But it may be significant that the most successful introductions were nonstaple foods that could be readily substituted for (or eaten alongside) native counterparts without incurring much risk or requiring a large investment of startup costs or additional labor. In this respect, the case of Roman Europe has some parallels with a later and even more momentous contact of cultures – the European conquest of the New World.

PEACHES, COWPEAS, MELONS, AND HOGS: OLD WORLD FOODS IN SOUTHEASTERN NORTH AMERICA

The exchange of foods between the Old World and the New was to have even more dramatic consequences for cuisines than did the expansion of Rome. North and South America, separated from the other continents by vast oceans, were the last major landmasses to be colonized by *Homo sapiens*. Only at the height of the most recent glacial advance was this water barrier breached, as low sea levels exposed an expanse of land between Siberia and the Alaskan peninsula. Bands of hunters made their way into the North American interior by this route, and rising seas subsequently isolated Americans from the rest of the world until 1492. The cultures that confronted each other as a result of European exploration had been evolving separately for at least 10,000 years.

Since 1492, few cuisines on either side of the Atlantic have remained untouched by the consequences of this giant exchange network linking

the Americas with Europe, Africa, and eventually even the Far East. As trade and exploration blossomed, indigenous societies of North and South America were both sources and recipients of novel foods. In some regions, the impact of these imports on traditional agriculture and diet were limited, at least initially; in others, exchange of foods was facilitated by ongoing interaction between the social realms of indigenous people and the invaders. A blending of elements from both hemispheres was frequently the outcome of rapid conquest and colonization – Mexican cuisine, with its chicken, beef, and cheese-filled flour tortillas, is an excellent example of how this sort of relationship played out. There were also some New World foods, such as the tomato, the Andean (“Irish”) potato, and chili peppers, that proved to have worldwide appeal.

The varying fates of foods that were caught up in the post-Columbian exchange present a bewildering array of potential causal factors. Why were some items adopted and others ignored? We can perhaps isolate some of the key causal factors by focusing on a specific case in which the exposure to and adoption of new foods initially took place gradually over a period of centuries. One such case involves the indigenous peoples of the interior southeastern United States, in parts of what is now Georgia, Alabama, North and South Carolina, and Virginia. In this region, contacts with Europeans were at first largely indirect, taking the form of trade through Native American intermediaries. This initial period of indirect contact, called the Protohistoric, lasted from the first appearance in indigenous communities of trade goods from European colonies on the coast during the sixteenth century to the arrival of European settlers hungry for productive farmland in the eighteenth century. This turn of events changed the nature of exchange considerably by bringing competition for land and direct exposure to Euroamerican methods of farming and land management into the picture.

The peoples of the interior Southeast, which included the Creeks and Cherokees as well as less widely known groups such as the Yuchis and Saponis, were well positioned to take what they wanted from European sources while remaining free to ignore the rest. This pattern shows up clearly in the archaeological record, where the range of trade goods is relatively restricted and initially reflects preferences for glass beads and metal objects. These goods came primarily from Native American middlemen who were able to profit from direct contact with European trading posts, buying cheap near the coastal settlements and selling dear to peoples of the interior.¹⁵ Whether these exchanges included any foodstuffs is difficult to say, because the exotic plant and animal

remains that do show up in excavations give no indication of whether or not they grew locally. Unlike metal spoons and kettles, organisms have some ability to relocate without human assistance.

In fact, one of the first Old World plants to appear in the refuse dumps of Native American villages was quite capable of colonizing the landscapes of the Southeast without human intervention: the peach, *Prunus persica*.¹⁶ The peach came originally from Asia; however, by 1492 it had long been cultivated in European orchards. Historical documents indicate that peaches may have arrived on American shores as early as Columbus' second voyage, after which it became rapidly established in the Caribbean. Early in the 1500s peaches were being raised at Spanish mission settlements along the Gulf and Atlantic coasts. What happened next is not entirely clear, but by some means peaches made their way into the diets of indigenous peoples of the interior. Peach pits become one of the main constituents of archaeobotanical assemblages from villages that had only indirect contact with European settlements. The most likely scenario to explain this pattern is that the peach became established as an escape from cultivation, colonizing disturbed spots on the landscape. A discarded peach seed is likely to sprout and may even survive to bear fruit in three to five years. Any mammal that eats fruit – humans included – can disperse the seeds to a new location. The ecological weediness of the peach tree no doubt accounts for the fact that the tribes of interior North Carolina believed it to be a native plant.¹⁷

Once captured from the wild, the peach became a component of established groves maintained by Creek and Cherokee villages. Their presence was noted there by John Bartram, the naturalist and explorer of southeastern landscapes. Peach trees grew alongside the native fruit trees such as persimmon and plum in tended groves that Bartram recognized as "orchards," although they were managed in a more casual manner than the European versions with which he was familiar. The peach seems to have been easily adopted into the existing system of arboriculture. In addition to numerous documents that mention the cultivation of the peach by indigenous southeastern groups, the carbonized fragments of the distinctively ridged stones, or pits, are abundant and nearly ubiquitous on sites dating to the late seventeenth century and beyond. The abundance of the pits is partly due to their extreme durability even when burned, but even taking this bias into account, the peach was a successful, if inadvertent, introduction to Native American diets.

Other notable plants found on postcontact Native American villages in the Southeast are the cowpea, or blackeyed pea (*Vigna unguiculata*) and the watermelon (*Citrullus vulgaris*). Seeds of these domesticates are neither abundant nor commonly encountered on sites of this time period, probably in part because they were less durable and perhaps less often exposed to fire than peach pits were. Both are native to Africa. How they arrived in the Southeast is not known for certain, but Spanish colonists on the Gulf and Atlantic coasts included them among the founder crops planted at missions. Watermelons were eagerly taken up by the Natchez Indians of the lower Mississippi valley according to the eighteenth-century chronicler Le Page du Pratz, and their seeds are sometimes found in charred form on archaeological sites of the Contact period.¹⁸

Notably absent from, or only sparsely represented at, Protohistoric sites are the bones of introduced domesticated animals, such as cattle, hogs, and horses. These animals did make their way into indigenous economies, but this change occurred later in the eighteenth century, during the period of European settlement of the interior. Similarly, the Eurasian cereal crops on which European farmers depended – most notably, wheat – are absent. The role of maize as the staple grain remained consistent and this crop even came to dominate the farms of Anglo-American colonists, becoming a key ingredient of southern cuisine.

So how is it possible to account for these patterns of adoption of exotic foods? In the Protohistoric period, coercion was not an issue as it was at the Spanish missions on the coast, where forced settlement and conversion were common. Being somewhat buffered from direct contact with Europeans and their food traditions, interior peoples made their own decisions. These were guided by the same combination of conserved cultural knowledge and evaluation of costs and benefits that influence all human food choices.

Relative conservatism in agricultural practice is a well-known phenomenon, one that often frustrates development experts pushing productive hybrid crops. However, resistance to novelty has an important function because it is a manifestation of centuries or even millennia of experience in a particular environment. Agricultural systems are not just random collections of strategies; they contain many connected and interacting components. The kind of restructuring that would be required to switch to a new staple crop thus carries significant risk of failure because of possible negative and ramifying effects on other parts

of the system. Some degree of resistance to novelty is, therefore, probably an adaptive feature of cultural inheritance. If it ain't broke, don't fix it, as the saying goes. Adherence to inherited cultural standards probably has something to do with the failure to adopt at least some exotic crops and livestock.

The consideration of costs and benefits can also shed some light on which novelties were adopted. All of the three plants mentioned so far – peach, watermelon, and cowpea – have in common relatively low production costs and high benefits. Low costs derive from the fact that they all resemble familiar native crops: fruit trees such as persimmon (peach), the common bean (cowpeas), and native squashes and pumpkins (watermelon). Adding them to existing fields and gardens required minimal startup costs because systems of arboriculture and crop gardening were already in place. The risk of hunger that might have accompanied a wholesale replacement of traditional crops remained low as long as the new crops were dietary supplements, not staples meant to supply a large proportion of a population's food energy. Finally, the plants themselves are robust enough to flourish in the Southeast under human care that was expert but not highly complicated technologically, relying not on fertilizer, hothouses, irrigation, and plows, but rather on fertile alluvial soils, a temperate climate, and knowledge of the environment accumulated over millennia.¹⁹

THE GLOBAL REACH OF FOODWAYS

The spread of Near Eastern agriculture, the Romanization of European cuisines, and the introduction of Old World crops into the Americas illustrate somewhat different scenarios by which dietary customs change as a result of contact with alien or little-known cultures. Many similar scenarios have been enacted worldwide, thanks to improvements in long-distance communication and the technology of transportation. Once a food novelty is acquired, the complex dynamics of cultural processes influence people to adopt some food habits and not others. Successful transfers have played a major role in shaping the eclectic cuisines featured in highbrow restaurants today.

However, the consequences of intercultural exchange of foodstuffs and food traditions are not always so benign. Cascading ecological effects sometimes follow from the introduction of exotic animals and plants into new settings, often done in hopes of establishing harvestable

populations closer to home. The ecological impacts are even more extensive when agricultural development introduces whole suites of crops and techniques of land management. Thus, an inevitable consequence of the world travels of culinary traditions and their material counterparts – extinctions.

8

EXTINCTIONS

Whether or not fire can be considered as an essential human trait, it has surely been the foremost medium through which mankind has shaped his environment.

Stephen J. Pyne, *Fire in America*

The industrialized nations of the early twenty-first century are often cast as villains in the drama of global environmental change. Certainly there is much truth in this characterization; however, the simplistic dichotomy between profit-seeking development-at-any-cost and living in harmony with nature is merely a stand-in for a much more complex reality. The distinction between destructive/artificial and harmonious/natural is a useful rhetorical device, but, it emphasizes extremes, whereas most human societies have settled somewhere between them.

Extinctions are only the most extreme example of human modification of the natural environment, but they are familiar to most of us because they are heavily publicized. Extinction is indeed forever (as far as we can say right now, given the status of cloning technology), and we are right to be alarmed at the rapid rate of extinctions that are due to habitat loss, environmental toxins, and other anthropogenic (human-caused) effects. However, modern industrial societies are not unique in having a substantial impact on the habitats in which they live. After all, the people of bands and villages and ancient urban centers had to eat just as we do. They managed the landscape using fire, cleared agricultural fields and gardens, and built huge stone monuments in the rain forest. The impacts of these activities, however, were in many cases limited in magnitude and spatial extent by the relatively small size of the human groups that practiced them. Population growth led some societies to exist right at the margin of sustainability – a dangerous place to

be when a critical variable, such as rainfall or the length of the growing season, failed to meet expectations. When this happened, societal disorganization and depopulation were the result (see Chapter 5).

What I hope to communicate in this chapter is that modern humans – including us, the earliest behaviorally modern *Homo sapiens*, and everybody who lived in between – have always shaped their environments. Hunter–gatherers occupied the land lightly, and their numbers were small, but still they burned vegetation to encourage game and make travel easier. In previously unoccupied lands such as North and South America and Australia, immigrating hunters made substantial dents in some animal populations. Farmers were more numerous, and in order to extract what they needed from the land, they had to make it productive by clearing off natural vegetation, planting crops, creating irrigation systems, and grazing their herds of livestock. On small islands, the arrival of people with their domesticates and other coresident species had the potential to cause widespread and severe changes in the landscape. Urbanization brought still higher population densities, more monuments, more complex and specialized economies, and empires that destroyed what they could not dominate.

It is not surprising that the adherence of small-scale, subsistence-level societies to a conservation ethic has been questioned in recent years. According to many ethnographic studies, there is little evidence that hunter–gatherers and traditional farmers make a conscious effort to conserve for the future.¹ This result, of course, pertains to modern people who have been studied by ethnographers, not “living fossils” untouched by the modern world. There is also the question of whether the statements made to anthropologists by a limited number of people are a sound basis for summing up a culture’s values. We need to know what people do, not just what they say they do or perceive as an ideal. Behavioral ecologists have, in fact, learned that traditional hunters do not always hunt sustainably; immediate needs sometimes outweigh any benefits of restraint. There are sound economic reasons why this might be so: Nondomesticated animals are not controlled by individuals, so they have the status of public goods. There may be informal use rights and sanctions against being greedy that are respected by individuals and groups. However, without strong enforcement of these rules, cheaters can get away with hunting to their heart’s content while others go hungry in obedience to a strict conservation ethic. There simply are too many disincentives to holding back when your neighbors are taking more than their share of a finite resource. There is also the matter of

future discounting – the devaluing of future rewards.² A bird in the hand is worth two in the bush, goes the proverb, and a peccary roasting over the fire fills the stomach in a way that a hypothetical future peccary cannot hope to match.

Even if ideals promote wise and restrained use of nature, they are often put aside when needs become critical. The same fate can befall taboos and other behavioral rules that act to limit unrestricted exploitation (even though this may not be their stated purpose). Immediate survival is a more urgent need than conservation, and for that reason sustainable resource use is in some ways a luxury of the well-fed. This is why anthropologists tear their hair out when development experts want to turn a savannah into an untouched game preserve without regard for the people who rely on it as a resource. Fortunately, ethnobiologists are getting in on the act more frequently today than in the past, helping to work out plans that prevent habitat destruction while also permitting judicious harvesting.

Manipulation of the natural environment spans a continuum not only within the human species, but beyond it. You do not need much of a brain to do it, though cognition adds enhancements such as being able to make inferences about what works and what does not, or to extrapolate from past experience to present and future needs. Some ecologists have recognized this tendency of organisms to shape their environments as a distinctive process called “niche construction.”³ Niche construction theory holds that modification of the environment plays a distinctive role in the process of evolution by natural selection. Organisms change their habitats in ways that influence their offspring’s survival chances; in this sense, the environment is inherited along with biological contributions from the parent such as DNA or an initial supply of food such as the endosperm of a seed, the white of an egg, or a placenta. From this perspective, the inherited environment must be factored into the traditional Darwinian equation of variation, inheritance, selection, and reproduction. Although the precise role that niche construction theory should play in evolutionary analysis is debated, the concept is a useful one that highlights the deep ancestry and adaptive value of environmental modification.

Inheritance of the built or modified environment is an easy concept to grasp when the behavior of parent and offspring are relatively inflexible and highly predictable. A wasp lays its eggs inside a fig; the larvae eat their way out and, if figs are still available, they continue the cycle by laying their own eggs. The fig-as-nursery strategy works well enough

that it produces more offspring than existing alternatives do. The system is intricate, perhaps even something to marvel at; however, it can be understood in a straightforward way using Darwinian concepts. The human version of niche construction is more complex, being more open to experimentation and learning-based modification than that of other species.

The remainder of this chapter is dedicated to environmental modification by *Homo sapiens* and its consequences. Today, habitat destruction, resource depletion, and the effects of global warming are happening so fast that it seems obvious that future generations will occupy a selective environment very different from the one that exists today. In the prehistoric past, such changes usually happened at a slower pace, so that they can be recognized only from the deep time perspective that archaeology offers. Some of the most hotly contested examples of environmental modification trace animal extinctions to human prowess as predator; the frequent coincidence of human colonization of major landmasses with multiple extinction events is well documented. However, questions remain about the precise role played by human hunters in wiping out entire species. For examples, I look first to the Pleistocene extinction of large mammals in the Americas, where human arrival coincided with a major shift in global climate. This conjunction of events makes it difficult to isolate causes of species loss, and some researchers question the plausibility of “overkill” as a sufficient explanation of the disappearance of mammoths, mastodons, a series of giant ground sloths, and other large mammals. Those who favor the overkill argument draw parallels with human colonization of islands, a situation that inevitably leads to rapid extinction of at least some indigenous species. These prehistoric examples often involve boats and commensal animals and plants – species that benefit from close association with humans – as well as domesticates. Island colonizations provide well-documented instances of overkill and often involve a complex web of ecological interactions that transform the human habitat. Finally, large-scale transformation of the landscape through the use of fire is an ancient practice that has served humans well as a management tool in many environmental settings. The history of fire management is well documented in Australia through paleoenvironmental records of pollen and the archaeological record of human activities. In contrast to the extinction examples, fire management illustrates some of the less catastrophic, and more benign (at least for people) impacts of niche construction by *Homo sapiens*.

MAN VERSUS MAMMOTH

The question of what caused the extinction of numerous large-bodied animal species at the end of the Pleistocene remains one of the most compelling and contested in both archaeology and paleontology.⁴ Similar extinctions occurred during the Late Pleistocene in many parts of the world, but only in the Americas has the timing of human colonization in relation to extinction events caused such controversy. For one thing, evidence of human occupation of the Americas prior to about 10,500 BC is exceedingly rare; only the Monte Verde site in Chile and the Meadowcroft rockshelter in Pennsylvania have gained wide acceptance as valid cases. These sites, however, provide no direct evidence that megafauna such as mammoths were hunted, although Monte Verde produced mastodon bones and skin that clearly indicate utilization. The relatively few mammoth and mastodon kill sites (numbering fourteen in all, using strict criteria for secure dates and clear associations with hunting activity) seem disproportionate to the kind of mass mortality that might drive an entire species to local extinction. Also, there is no indication that other large mammals were subject to human predation.⁵ Shouldn't there be such evidence, if humans hunted with such intensity and success as to cause a critically high mortality rate?

Unfortunately, there is no simple answer to this question. Even if such hunting activity was common, there might be other reasons for the scarcity of its archaeological traces. This position is the one taken by Paul S. Martin, author and staunch defender of the overkill hypothesis as applied to North America. He argues that a massive assault on megafauna caused high mortality over such a brief span of time that the probability of such sites having been preserved and then discovered by archaeologists is vanishingly small. However, a plausible explanation for the absence of evidence is a weak kind of support for any hypothesis. If, in fact, this scarcity of kill sites is due to some cause other than the infrequency of kill events in the past, then it is important to fully investigate these alternative causes and if possible establish their existence. For the moment at least, we are right to be concerned about the value of the overkill hypothesis given rather sparse support for the killing itself.

What else besides the smoking gun of kill sites might yield evidence for the causes of Late Pleistocene extinctions in the Americas? Kill sites alone, even if they were more abundant, would not provide conclusive evidence that people drove megafauna to extinction, only that these animals were frequent prey. Under what ecological conditions, then,

can hunting lead to extinction? Behavioral ecologists argue that this is an unlikely outcome simply because the scarcity of the target animal will cause a forager to switch to less valued but more abundant prey; in this scenario, hunters will not ignore a mammoth if they happen to stumble across one, but will not waste valuable time searching for a rare mammoth while ignoring smaller game that they could pursue instead. The diet breadth model predicts this outcome, offering an economic explanation for why foragers add items to the diet rather than focusing only on the most valuable ones, such as large-bodied mammals (see Chapter 3 for more on foraging theory).

To find out whether hunting might plausibly cause extinction when several alternative food resources are available, Bruce Winterhalder and Flora Lu constructed a simulation into which they entered data on a hypothetical forager and its prey.⁶ In addition to calories and time spent, they included information on the reproductive rates of both predator and prey. All of the values they used were hypothetical but plausible based on ethnographic and ecological knowledge. They then placed their virtual hunters in several different situations to see how the populations fared. Given only one resource, hunters stopped short of the maximum hunting pressure that would allow the prey population to persist; the human population stopped growing, allowing the prey to recover. With four resources, hunters behaved more or less as the diet breadth model predicts, broadening the roster of foods when the top ranked prey became scarce. However, the number two resource became extinct; its low rate of increase made it especially vulnerable and it folded despite the fact that there were other alternative targets. This outcome suggests that there is a catch to hunters finding something else to eat: It makes their population grow rather than remaining stable, putting even more pressure on all prey types. In the simulation, extinction of the number two resource could be avoided by adding another prey type that offered fairly modest net yields but also had a high rate of increase. This simulation, although it has the form of a simplified virtual world, has important lessons to impart about how predators might be able to affect prey populations and under what conditions. Overhunting can be inhibited even without intentional conservation, as long as people respond to scarcity by adopting a more eclectic diet and thus permitting key prey populations to replenish. However, a food type that reproduces slowly will have greater difficulty recovering from exploitation, unless there is an alternative, “extinction-resistant” food source to divert hungry foragers.

Some populations, then, are more vulnerable to extinction than others because of their life-history characteristics. This seems to be true of megafauna in general – their size is correlated with having relatively few offspring per birth and per lifetime, and they take a long time to grow to maturity. Humans are like this, too. Compare this situation with a small mammal such as a field mouse or cottontail rabbit; they have litters rather than single births, their young mature in a matter of weeks, and the mother is soon ready to mate again. In these species, mortality may be high because of predators, but they are resilient as populations because they can replace themselves rapidly. However, mammoths need time to make more mammoths, and a rapid increase in the mortality rate that is due to hunting (or any other cause, for that matter) might well make replacement impossible. Simulations show that extinction is a much more likely outcome given a rapid upswing in deaths, as opposed to a slow increase spread out over many generations.⁷ Virtual hunting based on real-world parameters can indeed result in extinction of megafauna, although only in the form of a full-on assault.

That megafauna are vulnerable to overhunting because they mature slowly and have few offspring has a solid basis in ecological knowledge. However, another component of the “blitzkrieg” or rapid overkill hypothesis formulated by Paul S. Martin is less well supported – namely, the persistent failure of large mammals to learn to evade and avoid human hunters. It may be difficult for a mammoth to hide in plain view, but other strategies are available, such as increased vigilance and avoidance of populated lands. This failure to adjust to human predation casts doubt on the efficacy of human hunters as the sole cause of megafaunal extinctions.

So far, direct evidence that humans hunted multiple megafaunal species to extinction is elusive. Principles of populations ecology built into a simulated Pleistocene world indicate that such an event could have occurred, but probably would not have unless the hunters were numerous and unrelenting, and had no reliable food source that could sustain their population. The timing of extinctions relative to human arrival in the Americas is not particularly compelling – some of these species disappeared well before humans arrived, whereas others seem to have coexisted with humans for centuries before dying out.⁸ Human hunters did remove some large animals from their respective gene pools; however, it is highly unlikely that they were the sole cause of extinction of any of the species that disappeared from the Americas at the end of the Pleistocene.

The Late Pleistocene extinctions in the Americas also coincide with major shifts in global climate. Changing patterns of temperature, rainfall, seasonality, and vegetation are clearly implicated in the die-off in a number of world regions.⁹ This seems to be the case, for example, in Europe where large animals had been human prey for at least tens of thousands of years (although hunting pressure provided an added stressor). The question remains as to what was so special about the Late Pleistocene climatic changes that caused the extinction of megafauna that had, after all, survived earlier events of this sort, including the rapid temperature shifts of the Middle Pleistocene that killed off mainly smaller species.¹⁰ The answer varies from region to region; however, in North America a strong case can be made that hunting was just one nail in the coffin of certain large-bodied species already stressed by habitat loss and seasonal food shortages. There is no single causal scenario that fits all regions and all extinct megafaunal species, although we can be certain that global-scale climatic changes had local-level impacts everywhere, which, in some cases, were exacerbated by newly arrived or more highly skilled human hunters.

INVASION OF THE ISLAND SNATCHERS

Extinctions that happen on continents are governed by a somewhat different logic than that which operates on islands, especially when very small landmasses are involved. There are a number of reasons why small islands are particularly vulnerable to extinction of endemic flora and fauna. Because of their relative inaccessibility, islands often accumulate an odd collection of terrestrial plants and animals that have floated, flown, or drifted in from continents and other islands. Successful colonizations by these immigrants are greatly influenced by chance factors such as storms, and vast oceanic distances reduce the likelihood of terrestrial animal species becoming established there. Large land animals have difficulty traversing great expanses of water. Birds have an easier time arriving on islands, as do smaller animals that arrive storm-borne on driftwood or other floating objects. In similar fashion, plant seeds must either remain viable after a journey in salt water or ingestion by a bird, or ride landward on the wind. The combination of limitations on dispersal, the influence of chance events, and relative isolation from founding populations creates island biotas that are individually distinctive. Animals and plants on small islands evolve in the absence of land predators that would otherwise maintain strong natural selection

for chemical and behavioral defenses, which of course makes them vulnerable when predators do finally arrive. Even retreating to sheltered habitats is not an option when land area is limited.

Enter a large mammalian omnivore – *Homo sapiens*. Humans have resources such as boats and navigation skills, and they took advantage of these in prehistoric times to colonize new lands. This process has been investigated in depth and detail by archaeologists working in the Pacific Islands, where human colonization can be tracked in a time-transgressive path from west to east. These immigrants usually brought with them domesticates such as the dog, yam, and chicken and, presumably, a set of tools and skills with which to start a new life. This must have been a frequent occurrence, because human populations can grow quickly enough to outstrip the ability of a small land mass to support them.

Archaeologists have studied many such islands, but one of the most thoroughly documented – and most controversial – is Easter Island (Rapa Nui).¹¹ This small (171 km²) island in the southeastern Pacific Ocean is remote from both the mainland of South America and from the archipelagos and solitary islands to its west (Figure 2.1). Rapa Nui was colonized late in prehistory: most recent estimates based on radiocarbon dates converge on AD 1200. These dates come from a site at which layers of sediment have accumulated with minimal disturbance over several millennia. Their excavation revealed a clear separation between pre-AD 1200 layers in which root casts and stains of the Easter Island palm are abundant, and upper sediments rich in signs of human activity such as charcoal, artifacts, and rat bones. Sediment cores taken from various locations indicate erosion on slopes, an influx of charcoal (probably from land clearance using fire), and a shift from trees to shrub and herb vegetation. During the period of occupation, people switched from using trees to using shrubs as fuel – a sign of deforestation. Rats also had an impact on the *Jubaea* palm forests, eating the nutritious seeds and leaving behind the remnants of gnawed endocarp (the hard shell of the fruit).

These environmental changes are by now well documented and largely noncontroversial. Nonetheless, debate continues, fueled by the remaining gaps in the archaeological and paleoenvironmental records. One of these gaps is the story of human population growth and decline, which can only be inferred from historical records of Europeans and the characteristics and numbers of archaeological sites and agricultural features on the landscape. Population estimates vary widely and play

a crucial role in determining whether or not the Rapa Nui case is one of “ecodisaster” and societal collapse. Biologist Jared Diamond made a famous case for wanton environmental destruction brought about as overpopulation drove agricultural clearing, timber harvesting, and fuel collecting to unsustainable levels. Even status competition is implicated in the disaster, driving the construction of the giant statues (*moai*) whose transport required a constant supply of the smooth palm stalks that served as rollers. Diamond argues that the labor requirements for moving these massive stone effigies imply an islandwide population of many thousands at the very least. Ultimately this population exceeded the ability of the island to support it, and famine drove people to extremes. Oral traditions speak of cannibalism and an abandonment of traditional housing for more easily defended caves.

Diamond’s interpretation of Rapa Nui prehistory deemphasizes the role of rat predation on palm seeds, which Terry Hunt believes was a crucial factor in the demise of the native forests. Hunt argues that the numerous gnawed palm endocarps provide ample evidence that *Rattus exulans*, an exotic species introduced by human colonists, consumed enough of the seeds to make a substantial dent in palm populations. Without enough seeds to germinate, mature forests were not replaced; instead they retreated to isolated patches of relatively rat-free territory before disappearing entirely. Rats have an extraordinarily high reproductive rate – under optimal conditions they double in number every forty-seven years. Unrelenting predation could, plausibly, have had a devastating effect on the palms – assuming, of course, that the rats themselves had alternative food sources to keep their populations from crashing in response to the palm shortage (presumably they did). Thus, in Hunt’s version, rats carry a larger share of blame for deforestation than human farmers do. Rather than a societal collapse and descent into famine, cannibalism, and interpersonal conflict, Hunt argues for the persistence of a small Rapa Nui population after deforestation, maintained by a sustainable system of agriculture that made use of intensive techniques such as stone mulching to retain water.

Although these alternate versions of the Rapa Nui story differ in their emphasis on human mismanagement and the catastrophic nature of the human population’s decline, they agree on most of the basic facts. Rapa Nui was first colonized between AD 800 and 1200, and many indicators exist of deforestation and erosion after the latter date. No one seems to dispute that rats ate palm seeds or that the island’s human occupants erected statues and practiced intensive agriculture, or that the arrival of

humans had enormous ecological impact. All recognize the particular vulnerabilities of Rapa Nui as a small island, drought-prone, biotically impoverished, and marginal for agriculture.

More evidence will fill in gaps in knowledge and provide important details, but they will not resolve the debate. This is so because it is difficult to avoid extracting from the human history of Rapa Nui a cautionary tale about the evils of unrestrained exploitation of nature. Scientists are usually careful to distance themselves from such judgments, at least when they point the finger at victims of European conquest and exploitation; however, it would be naïve to say that they have no opinions about culpability or at least the degree to which human activity destroyed or extirpated entire species.

The issue of moral culpability is ultimately not a productive one. People everywhere will do what they need to survive, even if that means sometimes sacrificing future benefits for present and urgent needs. Human groups farm and hunt and gather in a sustainable fashion when they are relatively small; however, as they grow larger, they face competition with other such groups and the effects of resource depression and declining agricultural productivity. They always struggle to maintain a reasonably good life, with enough food and companionship, and want the best for themselves and their loved ones. They always experience conflicts between individual/family and group interests. It must be an enormous challenge to care about the ultimate fate of the earth or global responsibilities when simply surviving another day is a major effort. Those of us who are comfortable and can see the big picture have a responsibility to do what we can to rein in destructive practices. That goal is better advanced by scientific investigation than by finger-pointing.

If we look more closely at what went right, rather than what went wrong, we get a glimpse of how the human facility for managing the landscape is put to the test in marginal habitats. In more forgiving settings, such strategies can yield significant benefits for human populations while transforming ecosystems, not through mass extinctions, but by favoring some species over others. This is the route taken by initial domestication of some plants and animals, but it does not always turn foragers into farmers. Before agriculture, humans had at their disposal a universal tool for environmental modification – fire. Controlled burns became a globally distributed method of enriching the supply of food on which people depended.

FIRESTARTERS

As I write this,¹² firefighters are just beginning to get control over one of the largest fires in southern California's history. Although an arsonist was responsible for this particular blaze, both human-set and natural fires have long been a part of the region's ecosystem. Today, they threaten property and take lives as they burn uncontrolled; however, it was not always so. For millennia prior to European settlement of North America, indigenous peoples appropriated the potentially destructive power of fire to create productive habitats for themselves. In California, periodic burning is essential for maintaining the open parklands in which oak trees can develop large crowns, yielding the acorn crops that helped to support substantial prehistoric human populations.

The controlled use of fire to transform human habitats has an ancient lineage, but in most parts of the world the practice has been abandoned or is forbidden under current laws. There is, however, an exception that offers an unusual opportunity to observe fire management in action. In arid regions of Australia, where agriculture and livestock ranching are recent European introductions, indigenous people have been burning the landscape for thousands of years. Today that practice is being revived. In the western desert of Australia, anthropologists Doug and Rebecca Bird have studied the effects of burning on the foraging efficiency of the Martu people.¹³ In Martu lands, fire suppression has been official policy for more than fifty years. The resulting landscape is a monotonous one, dominated by spinifex grass (species of *Trodia*) and interrupted by a few, but very large, burned-over patches. However, with Martu once again burning off the spinifex, the buried seeds of a wide variety of useful plants have a chance to germinate, creating a complex and varied vegetational mosaic. Postfire vegetation is rich in edible fruits, tubers, and seeds and attracts game birds (such as bustard). Even the process of burning is integral to a traditional form of hunting small game favored by women, who look for tracks and probe animal dens exposed as the fire spreads.

Unfortunately, we do not know how long the Martu and their ancestors have been burning the western Australian landscape. However, in the arid lands of central Australia a recent study of the carbon isotope content of eggshells of two large landbirds, the emu (*Dromaius*) and the now-extinct *Genynornis newtoni*, have shed some light on changes in vegetation some 45,000–50,000 years ago, when initial human

settlement of Australia is thought to have occurred.¹⁴ Researchers compared the carbon isotope content of eggshells of these two species in order to estimate how much of their diet was comprised of drought-tolerant grasses, which are usually C_4 plants. Between 45,000 and 50,000 BP, emus switched to eating fewer of these drylands grasses, substituting the C_3 species typically found in less open and somewhat moister habitats. *Genynornis* was less fortunate; a specialized grass-eater, it became extinct. People may have hunted these giant birds – it is hard to look at a picture of one and not think of giant drumsticks like the ones featured in the 1961 film *The Mysterious Island* – but vegetation change is also implicated, and people may well have caused it. Frequent controlled burning transformed large expanses of grass into a mosaic of smaller patches of (nonedible) spinifex and other C_4 grasses mixed with species-rich patches of (mostly) C_3 herbs and shrubs.

CHEWING THE SCENERY

No matter what we do for a living, we all eat the land. Habitat destruction can exterminate a species just as effectively as killing the animals one by one. The overkill route to extinction requires a convergence of special conditions that overcome the tendency of hunters to find alternative sources of food when favored prey become scarce. With sufficient experience of human hunters, animals become wary and harder to capture. Without alternatives, human populations shrink, giving the prey populations a chance to recover. However, some species are especially vulnerable to human predation because they have a low rate of reproduction that may be unable to withstand a large increase in hunting pressure that happens over a single generation. Combined effects of predation and climate-induced shortages of food are particularly devastating and may explain the Late Pleistocene disappearance of some megafauna, such as the mammoth and mastodon of North America.

The flora and fauna of islands are also susceptible to disruption; their populations are small, and, in many cases, they have evolved in the absence of large predators. Human arrivals on small islands can initiate a cascade of ecological events with far-reaching consequences. On Pacific Islands, the first colonists brought rats, dogs, and chickens that had their own impacts on native animals and plants. They cleared forests to plant crops that were not always well suited to the landscape and demanded creative solutions in the form of intensive agricultural techniques such as irrigation and mulching. Whether or not islanders

could foresee the consequences of their actions down the road, they had an immediate need to make a living and acted accordingly.

Islands have their own unique set of limiting factors that challenge human attempts to increase productivity. Larger landmasses are more resistant to practices that transform vegetation on a large scale. Australian landscapes bear the stamp of burning by indigenous people, which increases the quantity and variety of available plant foods and facilitates hunting. The antiquity of this practice varies across the continent, although it seems to have arrived with some of the earliest colonists as much as 50,000 years ago. The people who first used fire as a management tool did cause extinctions, not as a result of “overexploitation” but as a no doubt unintentional consequence of enriching their own resource base.

There is no question that prehistoric people modified their environments in ways that once were considered unique to industrialized Western cultures. The scale and magnitude of these effects remained limited by relatively small population sizes and technologies that relied mainly on human labor. Modern industrialized societies have greater potential to do harm to the environment in ways that will affect the prospects of many future generations. However, the conflict between individual and community interests still governs many decisions about how we extract food from other organisms. Restraint in use of resources works if everyone cooperates, but without enforcement, there is usually someone willing to step in and consume what others deny themselves. And when the choice is between feeding your family and conserving for the future, people do what any other evolved organism would do: whatever it takes to survive.

FINAL THOUGHTS: ANCIENT FOODWAYS AND CONTEMPORARY CONCERNS

What the future holds for human food habits is anyone's guess. Our physiological and anatomical equipment is going to be more or less the same for a long time to come. The past of our species and its ancestors has done its work to shape us, for better or worse. Medical and genetic technologies still hold surprises, and some of the constraints of being *Homo sapiens* – primate, mammal, and heterotroph – may yet be relaxed. Gene therapy for metabolic disorders, pills to prevent fat accumulation, and vitamin-enriched rice cultivars are just a few of the developments on the horizon that have the potential to improve human nutritional status. But tweaking the organism will not erase millions of years of evolutionary history.

NOSTALGIA FOR THE PLEISTOCENE

One aspect of that heritage that causes health problems today is the tendency that many of us have to overindulge in fatty and sweet foods. In part, these preferences (which are not universal, but vary from one individual to the next) are a legacy of our millennia spent as hunter-gatherers, when sources of sugar and animal fats were not as easy to acquire as they are today. Foragers could afford to eat their fill of fruits, meat, and fat because they were seldom in danger of chronic overindulgence. High activity levels kept hearts strong and burned body fat.¹ Supposedly, we remain in the grip of these preagricultural urges, which are no longer adaptive in a world of superabundant breakfast cereal, fast food, and torpidity. Maybe. But all of us, past and present, are capable of making choices that override the pull of ancestral appetites. We are not their helpless victims.

Limiting the amount of fat and sugar we consume no matter how much we want them is one way of exercising the improvisational ability that comes from being human. That way we get to keep the benefits of advances in food technology that give us bread and yogurt and meatloaf while keeping our appetites under control. Such a moderate approach does not appeal to everyone, however. There are those who advocate a return to a Paleolithic-style diet that emphasizes lean meats, seafood, fresh vegetables, and fruits and avoids grains, dairy products, salt, and all processed foods.² There is ample research to support the health benefits of such a diet; however, it is not clear that turning back the clock 10,000 years is the only way to optimize nutrition (although it nicely illustrates human creativity and intelligence in food choice). Agriculture does have its nutritional drawbacks; it is a strategy that emphasizes quantity over dietary quality. However, at the global level, abandoning it is not an option.

And giving up cooking, as recommended by raw food enthusiasts, may be taking things too far.³ The fad for uncooked foods (not to be confused with the Paleolithic diet, which emulates preagricultural, not pre-fire, eating patterns) has some advantages, such as preventing the loss of some nutrients that are damaged by heating. But besides ruling out many of the foods that taste buds delight in, a raw food diet eliminates the rewards of cooking as well as the drawbacks. Cooking caught on for a reason; not only is it easier on the teeth and jaws than the tearing and crushing of hard, fibrous, and elastic materials, but it has the benefit of breaking down the compounds in food in ways that facilitate the extraction of nutrients. Chemical and mechanical processing of the foods we eat sometimes enhances its nutritional value, and sometimes diminishes it, depending on characteristics of the food, the consumer, and the process.

Humans are remarkably resilient when it comes to food. We are neither obligate vegetarians nor obligate carnivores, in spite of what some diet books claim. We can eat almost anything and can easily remain well nourished by maintaining a varied diet. People can tolerate hunger for long periods, and even fast intentionally, hoping to cleanse the body or purify the soul, or induce visions. If we choose, we can even indulge in extreme and highly restricted regimes that require vigilance to ensure adequate nutrition. Paradoxically, our flexibility as a species with regard to diet allows us the freedom to constrain ourselves as individuals in ways our ancestors would probably find incomprehensible.

HUNGER ON A CROWDED PLANET

The time depth of an archaeological perspective reveals many instances of the struggle of human groups to cope with diminishing or scarce resources. Being consistently well fed is a recent innovation, and one that depends on a complex web of social interactions. It is a privilege of the relatively affluent. Today, inequities in wealth, power, and access to resources cause the supply of food to be distributed unequally, with some having more than they need and others less. However, inequality is not the only barrier to the consistent and ample food supply that many of us take for granted.

Agriculture helped solve the problem of producing sufficient food from a limited area of land, but it introduced some new difficulties. One of these is the potential for further population growth, which fosters even greater dependency on food production. Commitment to a farming economy and high demand for arable land create conflicts with mobility, so that traveling between resource patches is no longer an option. Densely packed settlements run the risk of depleting local wild resources, including game, diminishing an important source of dietary protein and minerals. Domestic animals can take up some of the slack as a source of meat and milk products, provided that technological innovations or biological adaptations are sufficient to overcome lactose intolerance. Despite these negative consequences for health, agriculture spread, in part simply as a result of the fertility of farmers but also more widely through cultural contact. The dispersal of agricultural systems is a particularly compelling illustration of the sort of rapid change in foodways made possible by the unique humans system of inheritance, social learning, and individual innovation.

Today we face resource depression on a global scale, fueled by population growth. Fish stocks are being depleted at a rapid rate. Huge yields are required of agriculture, fostering dependence on hybrid crop varieties, chemical fertilizers, and toxic pesticides. Factory-style production of meat, milk, and eggs conflicts with the ethical impulse to minimize suffering of the animals that provide us with food. Understanding the past is not going to solve these problems for us; however, it can enlighten us about the long-term development of interactions between human populations and their food sources. Archaeologists can trace the evolution of agricultural systems from the earliest domesticates through intensification and sometimes to the point of crisis. For some ancient societies, such as the Maya and the Ancestral Pueblo, loss

of agricultural productivity had ramifying effects, displacing communities and disrupting the social order. That new societies emerged to take their place is encouraging, a testament to the durability of the human adaptation. That such crises emerge at all is an indicator that it is risky to live close to the margin beyond which population exceeds food supply.

Some of the methods that prehistoric farmers used to manage risk suggest low-tech solutions to local problems of agricultural productivity. Many of these are still in use today by the descendants of the people who built the terraced fields of the Andes and the irrigated rice fields of southeast Asia. The transfer of these technologies can take place over longer distances than ever before, thanks to modern communication networks. The same potential exists for bridging the gap between past and present by rediscovering ancient agricultural knowledge and putting it to work. Archaeologists can help repair some of the broken lines of cultural descent, disrupted by contact and conquest, along which this knowledge once traveled.

THE CONSERVATION CONUNDRUM

The growth and geographic dispersal of human populations demands more of everything from the environment. It also inflicts collateral damage on other species, sometimes in subtle ways but often to the point of extinction. Culprits include habitat destruction and fragmentation, industrial and agricultural pollution, and their subsequent cascading effects through the food chain. Although humans have affected the fates of plant and animal species in the past, constraints were in place that are not present today. Pleistocene hunters could sometimes accomplish massive kills; however, they lacked the storage technology that could have maximized the utility of their catch. Their populations were relatively small, and although they contributed in some regions to the extinction of Pleistocene fauna, they were not its sole cause. Extinctions caused by human predation have happened more frequently on islands, particularly under the demands of an agricultural economy. Today, under the burden of global warming, many species have become even more vulnerable.

The global warming debate raises another important topic related to the lessons of the prehistoric past: the employment of the natural/unnatural dichotomy in public discourse. Ancient conditions are sometimes construed as more “natural” than contemporary ones, with the implication that there is something polluting or corrupting about the historical

trajectory of our species. There may be good arguments in support of returning to ancestral patterns; however, too often the concept of naturalness is vaguely defined and inconsistently applied. Special diets sometimes take on the quality of a search for purity by eliminating the artificial trappings of culture. In similar fashion, critics who minimize the urgency of addressing global warming sometimes point out that extinction is natural. This claim is as meaningless as the one made by conservative Christians that the penguin pair-bond demonstrates the naturalness of monogamy. The question of human effects on climate is an empirical one, and the matter of how we should address the consequences of global warming, including extinctions, is both ethical and practical. It does not further this goal to sanctify anthropogenic extinctions by touting their naturalness.

The notion that ancient conditions are more natural than those of the present has also crept into discussions of conservation policy. Fire suppression in the United States was long practiced by forest managers as responsible stewardship. In addition to protecting property and maximizing timber production, this policy was intended to replicate as closely as possible the natural presettlement vegetation. However, indigenous peoples had been managing the landscape with controlled burns for at least several millennia prior to European arrival. The eastern United States was not covered with an unbroken forest, but rather with a mosaic of woods, parklands, and both active and abandoned agricultural fields. Some European travelers observed indigenous practices and commented on their effects on vegetation; nevertheless, the notion of a pristine wilderness became established as a foil to the ravages of progress (or neglected wilderness unimproved by savages, depending on one's perspective). The natural/unnatural dichotomy here has simply obscured a complex ecological history in which human impact has waxed and waned. As in Australia, human disturbance of natural vegetation actually improved conditions for the people who lived there by enhancing their resource base. Continued reliance on those resources encouraged sustainable practices, even if not supported by an explicit conservation ethic. Recognition that anthropogenic fire has been shaping the eastern forests since long before European arrival has stimulated a new respect for the value of these practices in modern forest management. Controlled burns are now the norm, chiefly because they reduce the fuel load that accumulates otherwise, but also to encourage deer to browse and to revive prairies and parklands that disappear as the forest canopy regrows. In this case, paleoenvironmental reconstructions

have had a measurable impact on conservation policy, casting doubt on assumptions about past Native American land use and the revival of “wilderness” as a conservation goal.

Conservation experts debate the relative merits of wilderness preservation versus an approach that includes people who live close to their food sources as subsistence farmers or pastoralists. Wilderness purists would like to eradicate all signs of human influence from protected areas, as if people were not part of the ecosystem. An extreme version of this philosophy proposes pushing back the clock to before the megafaunal extinctions of the Pleistocene.⁴ The rationale for this approach is that humans caused those extinctions, and reintroduction of megafauna (including some threatened African species) to the American Great Plains will restore the Pleistocene landscape as it existed before humans entered the continent. Is this a good idea? Aside from the question of motivation (do we need to make reparations for overkill?), Pleistocene “rewilding” runs the risk of predictable negative impacts on extant species, not to mention ramifying ecological effects. Predators that once kept populations of large herbivores in check have declined, and the notion of introducing cheetahs and lions to replace them is, quite frankly, a little bit scary. Ranchers are, understandably, wary of any introduction of carnivores to which their livestock are vulnerable. Pleistocene rewilding would not be a restoration, but rather an ecological experiment with considerable potential for unanticipated, and potentially catastrophic, ecological consequences.

FOOD, PREHISTORY, AND HUMAN NATURE

The ancient past has something to contribute to specific questions about food-related customs and practices that concern people today. However, the (admittedly noncomprehensive) tour through dietary prehistory that this book presents has a more general relevance to thoughtful folk who wonder why people behave the way they do. Eating and drinking take place everywhere, every day, in a remarkable variety of ways. They are fundamental. More than any other category of behavior, these essential activities reveal the broad range of human cultural and biological diversity, as well as the common heritage that makes us capable of such flexibility. The multimillennial perspective of archaeology and paleoanthropology allows us to grasp the importance of cumulative knowledge about food; cultural traditions help to stabilize and perpetuate strategies that work well in a given environment. However, cultural learning

also has the potential to promote food customs that have no particular survival benefit or even do harm (as when consumption of human flesh infects people with a deadly brain disease). Similarly, there is no practical reason to reject a bowl of nutrient-rich smoked grasshoppers; some cultures simply do not accept insects as food. Such beliefs can be deeply rooted and difficult to dislodge. Still, they can change, a testament to the malleability of the human mind.

I hope I have been able to show that all of these factors – cultural inheritance, biological inheritance, and the ability to innovate – have a role to play in formulating convincing explanations of why people eat the way they do. Biological evolution makes sense of many of the food-related traits that characterize us as a species and even helps to account for certain differences between populations, such as the role of dairy products. However, no one will get very far in explaining dietary diversity without exploring the constant tension between individual problem solving and the transfer and accumulation of cultural knowledge. Past and present, custom and invention, biology and culture: All of these, and more, silently inform every act of eating.

NOTES

INTRODUCTION

- 1 Robert Boyd and Peter Richerson are strong proponents of the view that much of human behavior reflects a unique, species-specific compromise between the costs of learning and the risks of imitating strategies that do not work. These risks tend to be greater when environments fluctuate in a way that makes the copying strategy highly unreliable. In contrast, relatively stable environments encourage imitation as a labor-saving device that keeps the costs of learning to a minimum. See Boyd and Richerson (1985) and Richerson and Boyd (2005).

CHAPTER 1: ANCESTORS

- 1 This chapter draws heavily on Rowe (2004), Wood and Constantino (2004), Dawkins (2005), and Tudge (2000). The latter two are accessible introductions to the history of life on Earth for the nonspecialist.
- 2 The term “hominin” has come into common use by anthropologists relatively recently. This change has occurred because molecular evidence indicates a closer relationship between humans and the great apes (orangutans, gorillas, and chimpanzees) than was previously recognized. Many anthropologists argue that this discovery calls for a rearrangement of primate taxonomy that lumps humans and the great apes together in the family Hominidae. In much of contemporary literature, therefore, “hominid” no longer refers to humans and their extinct bipedal relatives, which are now grouped together in the Tribe Hominini within subfamily Homininae. Thus, “hominin” is “hominid” in the older literature; however, both terms label the same taxonomic group – only the levels within the taxonomy have changed. The reclassification and its effect on terminology are not universal, being a matter of taxonomic opinion. This is important to know if you do further reading in human evolution, but the details can be left safely to the taxonomists. To

delve further, see Wood and Constantino (2004) or check any up-to-date textbook in biological anthropology.

- 3 The recently described fossil remains of *Ardipithecus ramidus*, a hominin that lived in the Afar region of present-day Ethiopia some 4.4 million years ago, challenges this woodland-to-parkland scenario. *Ardipithecus* was an inefficient biped that had anatomical adaptations for climbing and walking along tree limbs and is associated with fossil remains of other animals characteristic of woodlands. See White et al. (2009).

CHAPTER 2: BEGINNINGS

- 1 Dart's interpretation of hominin diet on the basis of South African bone beds is discussed and critiqued in Brain (1995).
- 2 Lee (1968, 1979).
- 3 Washburn and Lancaster (1968).
- 4 The idea that the sexual division of subsistence labor and cooperative parenting gave rise to the nuclear family was further developed by Lovejoy (1981).
- 5 Tanner (1987); Tanner and Zihlman (1976); Zihlman (1978).
- 6 O'Connell, Hawkes, and Jones (1999); Ragir (2000); Wrangham et al. (1999).
- 7 See Domínguez Rodrigo and Pickering (2003) for a review of the controversy.
- 8 For more on the use of bone chemistry in paleodietary studies generally, see Ambrose and Krigbaum (2003), Katzenberg and Harrison (1997), Larsen (1997), and Pate (1994). Trace elements and stable isotopes from early hominin skeletal material are discussed in Lee-Thorp, Sponheimer, and Van Der Merwe (2003), Mann (2000), Sponheimer and Lee-Thorp (2003), and Teaford and Ungar (2000).
- 9 Sponheimer et al. (2005).
- 10 Lee-Thorp et al. (2003); Teaford and Ungar (2000); Ungar, Grine, and Teaford (2006).
- 11 Hernandez-Aguilar, Moore, and Travis (2007); Lee-Thorp et al. (2003); Lucas, Constantino, and Wood (2008); Teaford and Ungar (2000); Ungar et al. (2006).
- 12 On the morphology of the human gut and its relationship to encephalization and brain development, see Foley (2001), Mann (2000), Milton (1999, 2003), and Ungar et al. (2006).
- 13 Ungar et al. (2006).
- 14 Chimpanzee use of such tools has been well documented by Hernandez-Aguilar et al. (2007), and similar behavior should have been present in the most recent common ancestor of modern apes and humans.
- 15 Paleoclimate is a complex and specialized field of research, and one that is constantly churning out new evidence. For recent assessments of Pleistocene

climatic conditions, particularly in relation to hominin evolution in Africa, see Teaford and Ungar (2000) and Ungar et al. (2006).

- 16 I use “cooking” as a catchall term for all practices that transform food in significant ways, whether chemically (for example, by heating and fermentation) or by mechanical means (grinding and pounding).
- 17 Anthropologist Richard Wrangham argues that cooking is far more than a digestive aid or aesthetic embellishment, but rather a fundamental human behavioral adaptation; for details, see Wrangham (2009).
- 18 On toxins in plant foods, digestibility reducers, and effects of cooking, see Etkin (2006), Stahl (1984), Wandsnider (1997), Wrangham (2009), and Wrangham et al. (1999).
- 19 Sources on early human control of fire include Bellomo (1994); Brain and Sillen (1988); Goren-Inbar et al. (2004); Gowlett et al. (1981); James (1989); and Karkanas et al. (2007).
- 20 Karkanas et al. (2007).

CHAPTER 3: FORAGING

- 1 Bar-Yosef (2002).
- 2 Henry et al. (2004).
- 3 Forster (2004).
- 4 NOAA (2004).
- 5 Thieme (1997).
- 6 Lombard (2005).
- 7 Shea (2006).
- 8 McBrearty and Brooks (2000).
- 9 Bergman (1993); Hoffercker (2005); Marlowe (2005).
- 10 Marlowe (2005).
- 11 Bergman (1993).
- 12 Bar-Yosef (2004).
- 13 Stiner (2002).
- 14 Henshilwood et al. (2001); Klein and Cruz-Urbe (2000).
- 15 Karkanas et al. (2004).
- 16 Piperno et al. (2004).
- 17 This relationship between resource abundance and food choice has been worked out more formally as the diet breadth model of evolutionary ecology. This model and others like it are used to show how variables would influence each other under very specific conditions that cannot be replicated in nature. Like experiments, they allow scientists to control conditions to get a better sense of cause and effect. For more on the use of models in archaeology, see Winterhalder (2002).
- 18 Stiner (2002).

CHAPTER 4: FARMERS

- 1 Especially in Old World archaeology, where chronologies have long been constructed with reference to historical documents, it is customary to report Holocene dates (representing the last 10,000 years) as BC or BCE (Before Christ or Before the Common Era) and AD or ACE (Anno Domini or After the Common Era) rather than years before present (BP). I use the BC/AD system from this chapter onward for Holocene sites.
- 2 Mueller et al. (2005); Schultz and Grady (2008).
- 3 Darwin (1859).
- 4 Harris (1989).
- 5 Rindos (1984); Smith (2001, 2007).
- 6 The “adaptive syndrome of domestication” was described by Harlan, de Wet, and Price (1973) and de Wet (1975) and further elaborated by Smith (1989, 1992). Zeder et al. (2006) summarize key morphological criteria used to document domestication.
- 7 Harlan et al. (1973).
- 8 Zeder (2001).
- 9 Zeder et al. (2006).
- 10 Armelagos (2005).
- 11 Patin and Quintana-Murci (2007).
- 12 Boone (2002).
- 13 Richerson, Boyd, and Bettinger (2001).
- 14 Gremillion (1997).
- 15 Jones (1936).
- 16 Smith (1989); Yarnell (1976, 1977, 1986).
- 17 Smith (2001).
- 18 Smith (1992).
- 19 Harlan et al. (1973); Smith (1989, 1992).
- 20 Gremillion (1996); Gremillion and Sobolik (1996).
- 21 Gremillion (2002).
- 22 Gremillion (2004).
- 23 Cane (1989).
- 24 Braun (1983).
- 25 Braun (1983); Buikstra, Konigsburg, and Bullington (1986).
- 26 Lyons and D’Andrea (2003).
- 27 Coe (1994); Katz, Hediger, and Valleroy (1974).
- 28 Nesbitt (2005).
- 29 Burger et al. (2007); Copley et al. (2003).

CHAPTER 5: HUNGER

- 1 Vander Wall (1990) describes food hoarding throughout the animal kingdom. Winterhalder (1986) discusses strategies for minimizing risk and their

- effectiveness in different environmental contexts. The range of human strategies for coping with food supply variability is discussed by Colson (1979).
- 2 Vander Wall (1990).
 - 3 Wilkinson (1990).
 - 4 Dirks et al. (1980).
 - 5 Lummaa (2003).
 - 6 Larsen (1997).
 - 7 Wilson (1987).
 - 8 Minnis (1991) discusses the properties shared by most famine foods.
 - 9 Sugiyama (2001).
 - 10 Minnis (1991).
 - 11 Conklin (1995); Travis-Henikoff (2008).
 - 12 Recounted in the popular book *Alive*, by Piers Paul Read (Harper Collins, New York, 1974).
 - 13 Travis-Henikoff (2008).
 - 14 Fernandez-Jalvo et al. (1999).
 - 15 Hurlbut (2000).
 - 16 Billman, Lambert, and Leonard (2000); Hurlbut (2000).
 - 17 Eradication of witches has been suggested as an alternative, nondietary explanation for the patterns of damage to human skeletal remains observed in archaeological contexts from the region; however, this explanation is not fully consistent with most cases of suspected cannibalism studied to date, according to Hurlbut (2000).
 - 18 Gill et al. (2007); Haug et al. (2003); Peterson and Haug (2005).
 - 19 Hodell (2005).
 - 20 Benson, Petersen, and Stein (2007); Benson, Berry, et al. (2007); Larson et al. (1996).
 - 21 Buikstra, Konigsburg, and Bullington (1986); Larsen (1997).

CHAPTER 6: ABUNDANCE

- 1 Vander Wall (1990).
- 2 Bliege Bird and Bird (1997).
- 3 Stanford (1996).
- 4 Although this research continues today, modern hunter-gatherers live within nation-states and, unless they are explicitly granted autonomy by those states, are vulnerable to exploitation, resettlement, and the pressures of deforestation and development. Some choose to live in a nontraditional way, and most take advantage of at least some elements of nonindigenous technology.
- 5 Hawkes (1992, 1993); Hawkes and Bliege Bird (2002); Kaplan and Hill (1985).
- 6 There is a large literature on this subject, pioneered by Hawkes (1991, 1992), Hawkes and Bliege Bird (2002), O'Connell et al. (2002), and Kaplan and Hill

- (1985), and continued by more recent generations of ecological anthropologists, including Bliege Bird and Bird (1997).
- 7 Hawkes and Bliege Bird (2002).
 - 8 Gumerman (1997).
 - 9 Dietler (1996); Hayden (1996).
 - 10 Wesson (1999).
 - 11 Pauketat et al. (2002).
 - 12 Blitz (1993).
 - 13 Welch and Scarry (1995).
 - 14 There is also good documentary evidence that the southeastern chiefs hosted feasts to which all were invited and to which all the guests contributed according to their means.
 - 15 Jones (2007).
 - 16 McGovern (2003).
 - 17 This recipe has been used to create “Midas Touch,” a commercially available beverage.
 - 18 Coe and Coe (1996).
 - 19 LeCount (2001).
 - 20 Bray (2003a, 2003b); Cook and Glowacki (2003); Goldstein (2003); Hastorf (1990).
 - 21 Reviewed in Jackson and Scott (2003).
 - 22 Coe (1994); Cucina and Tiesler (2003); Danforth (1999); Larsen (1997).

CHAPTER 7: CONTACTS

- 1 Giraldeau (1997).
- 2 Chapman and Crites (1987).
- 3 Hart (1999).
- 4 Prance and Nesbitt (2004).
- 5 Ammerman and Cavalli-Sforza (1979).
- 6 Gkiasta et al. (2003).
- 7 Anthropologists generally avoid the term “race” because it has negative connotations and seems to suggest deep biological divisions between human populations that tend to be different in physical appearance. In fact, these differences are small compared to the percentage of human genes that are shared across all populations. Many of them are selectively neutral; that is, they are alternate forms that function equally well. When populations cease to interact, their gene pools tend to “drift” in different directions, particularly if the founding subpopulations have different starting gene frequencies.
- 8 Richards (2003).
- 9 Chikhi et al. (2002).
- 10 Pinhasi and Pluciennik (2004).
- 11 Bentley et al. (2002).

- 12 Dietler (1990, 1996).
- 13 Dietler (1996).
- 14 Bakels and Jacomet (2003).
- 15 Waselkov (1989).
- 16 Gremillion (1993).
- 17 Gremillion (1993).
- 18 Blake (1981).
- 19 Gremillion (1993).

CHAPTER 8: EXTINCTIONS

- 1 Alvard (1998); Winterhalder and Lu (1997).
- 2 Tucker (2002).
- 3 Laland, Odling-Smee, and Feldman (2000); Smith (2007).
- 4 I have consulted a number of sources in summarizing the debate, including Barnosky, Koch, et al. (2004), Brook and Bowman (2002, 2004), Burney and Flannery (2005), Fiedel and Haynes (2004), Gillespie (2008), Grayson (2007), Grayson and Meltzer (2002, 2003, 2004), Guthrie (2006), Surovell, Waguespack, and Brantingham (2005), and Yule et al. (2009).
- 5 Grayson and Meltzer (2003).
- 6 Winterhalder and Lu (1997).
- 7 Brook and Bowman (2005).
- 8 Grayson and Meltzer (2003)
- 9 Barnosky, Koch, et al. (2004).
- 10 Barnosky, Bell, et al. (2004).
- 11 Anderson (2002); Burney and Flannery (2005); Diamond (2007); Grayson (2001); Hunt (2007); Mann et al. (2008).
- 12 2009 was a particularly active year for wildfires in California.
- 13 Bird, Bliege Bird, and Parker (2003); Bliege Bird et al. (2008).
- 14 Johnson (2005); Miller et al. (2005).

FINAL THOUGHTS

- 1 Lee (1979).
- 2 For a thorough description of Loren Cordain's version of the paleolithic diet, see the Paleo Diet Web site at <http://www.thepaleodiet.com/index.shtml>
- 3 Wrangham (2009) discusses raw-foodism at length, concluding that devotion to an entirely raw diet ignores the beneficial effects of cooking on energetic efficiency.
- 4 Rubenstein et al. (2006).

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